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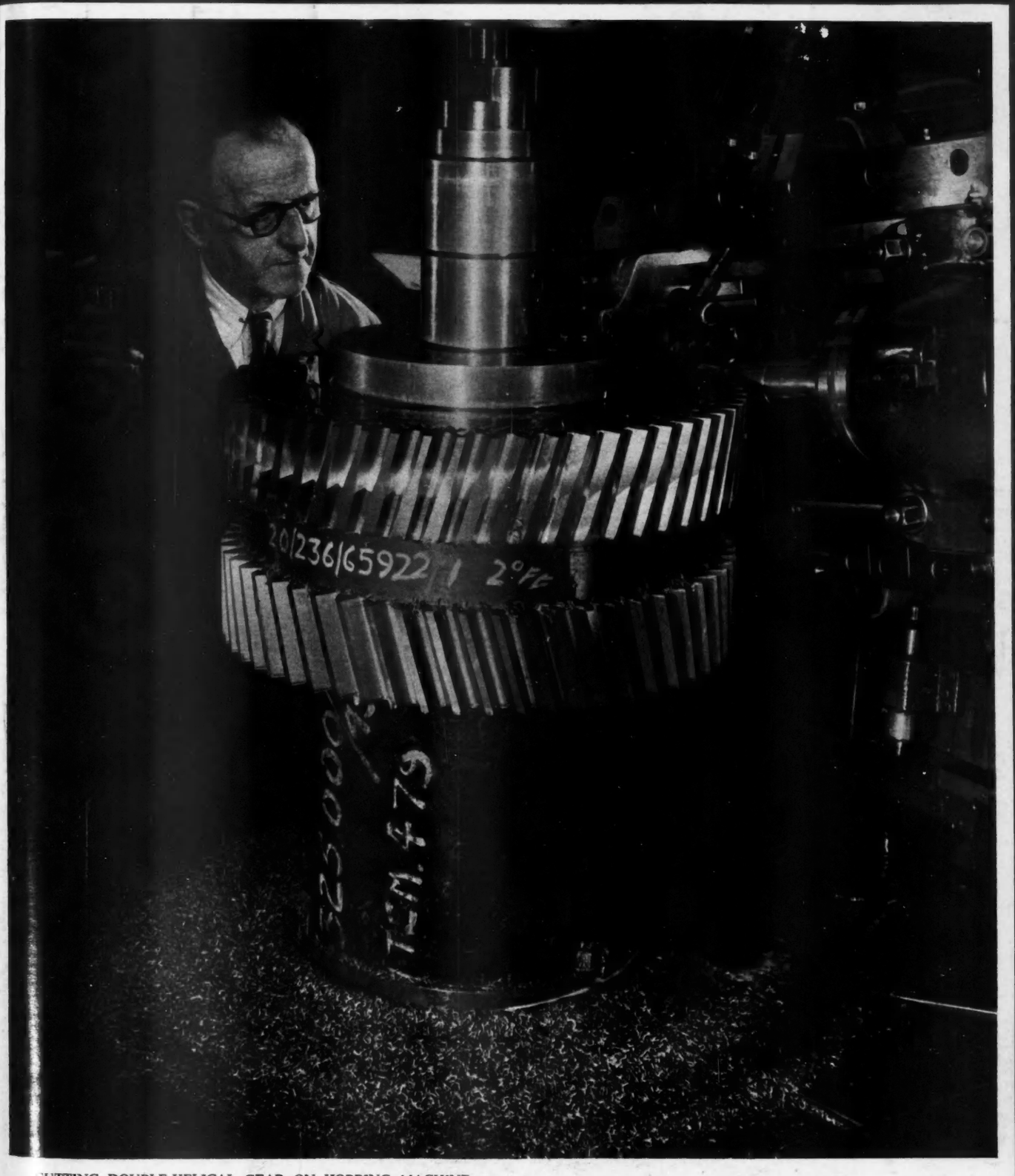

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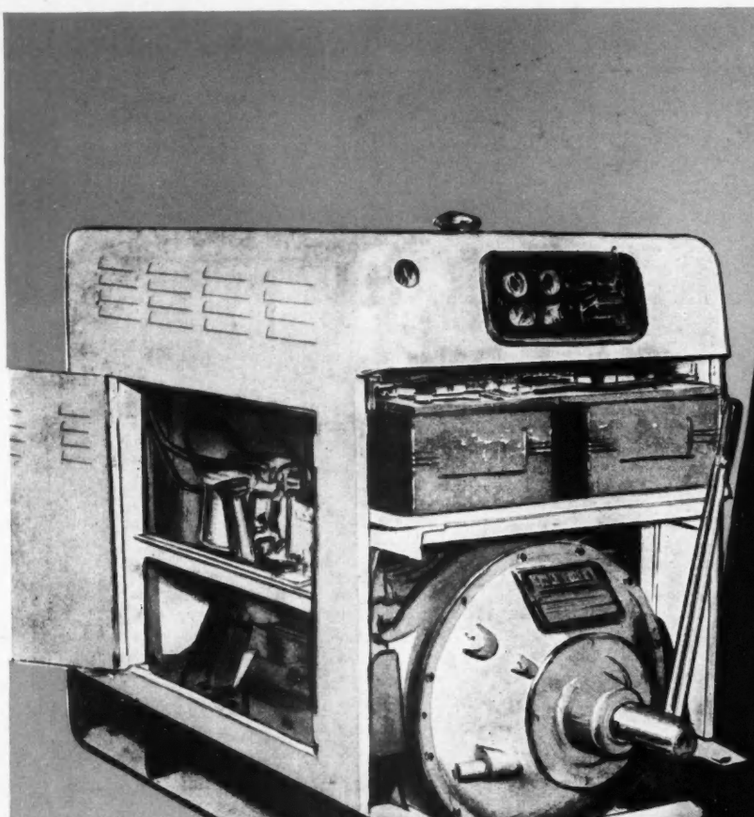

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THE ELECTRICAL INDUSTRY

ENGINEERS, and indeed the interested public, need not be ignorant of the activities of the different branches of the electrical industry. To those who can appreciate them the numerous papers read before the Institution of Electrical Engineers provide excellent instruction, while the annual reports of the British Electricity Authority and the Area Boards show in great detail what is being done to meet the increasing demand for power. There are many other such documents but perhaps the one of the most general value is the annual report of the British Electrical and Allied Manufacturers' Association, the forty-third edition of which, for the year ending March 31, 1954, was published last week.

This report covers a great deal of ground and its contents are indicative of the "liveliness" of a great industry. One of its outstanding features is the emphasis laid on consultation, not only between its own members, but with others connected with the industry. For instance, the formation of a Consultative Council to co-ordinate matters of policy affecting electrical and allied plant for the home and export markets has enabled the representatives of the Association consistently to urge that a first essential for national prosperity is an adequate programme of power station construction. Manufacturers are now in a position to provide the British Electricity Authority with some 2,000 MW of such plant per annum, an amount which is generally acknowledged to be the minimum required. In addition, the industry can supply 1,000 MW to overseas markets. As a result, a Government directive giving priority to potential export orders has been withdrawn; and the limit of 1,550 MW per annum imposed on power station construction has been expanded by 600 MW over a period of three years.

A liaison has also been established between the Association, the Authority, the Area Boards and the British Electrical Development Association to further the joint interests of the manufacturing and supply branches of the industry. Legislation on technical matters, international contract practices, exhibitions and standardisation are other examples, among many, of the subjects upon which combined action is being taken; and little argument should be necessary before the value of such co-operation to the national economy is established. The same may be said of the decision to send a representative British contingent to the World Power Conference, which is to be held in Rio de Janeiro this summer; such gatherings provide a good means of "showing the flag."

The review of the year's work, which forms an important section of the report, exhibits a natural optimism regarding the immediate past tempered by some anxiety regarding the future. The industry remained one of the chief contributors to the country's export trade, the value during the year under review amounting to £211·8 million. It is true that this figure was less than that for 1952, by some 3·4 per cent., as the inevitable result of the general reduction in world trade. It, however, showed a considerable improvement over the 1951 figure of £193·6 million. The bright spots were transformers, switchgear, turbines, radio equipment, lamps and locomotives, while motors, cables, valves, batteries and particularly domestic equipment, made a less satisfactory showing. In general, however, it is felt that there is no need to regard the future with pessimism, although it is clear that present activities must at least be maintained.

This view receives support from the statement that the hazards of export were never greater than they are to-day. Country after country is staving off economic crises by restricting imports, encouraging local industries and buying their barest needs at the cheapest price on the longest market. In fact, the change over from a buyers' to a sellers' market is now complete and the position, so far as this country is concerned, has not been improved by the increasing pressure of foreign competition, especially from Germany and Japan. This all provides a challenge to British electrical manufacturers, which they show no lack of eagerness to take up. Their activities are, however, hampered by factors outside their control.

In this atmosphere of light and shade there is one particularly black spot. It is necessary for the stimulation of electrical trade, both at home and abroad, that the activities of senior members of the industry should be fully and usefully engaged. As the report points out, however, the work both of the Association and of its member firms is being increasingly hampered by the inquiry of the Monopolies Commission, which is examining in meticulous detail the operations of the industry over a lengthy period. We have no doubt that the result will be a report of great interest to engineering historians. Whether, however, it will be "worth while goin' through so much to learn so little, as the charity boy said when he got to the end of the alphabet" may be doubted, especially at a time when the efforts of all concerned should be concentrated on the great national task the industry must fulfil

Weekly Survey

CRAFTSMANSHIP

Familiarity has, perhaps, bred a dangerous contempt for the warning that, to prosper, Britain must sell abroad her manufactured goods and that, to succeed in this, her goods must surpass in quality and workmanship those of her competitors. But it is still upon craftsmen and their skill that Britain is to a great extent dependent.

To foster a revival of skill and craftsmanship, the Alton and District Chamber of Commerce have organised an annual Trades and Craftsmanship Exhibition, which, it is hoped, will not only provide an opportunity for handiwork to be displayed, but will also encourage young men to enter those trades in which skill and training are the two essential qualifications. The Exhibition, which was held in the Assembly Hall, Alton, Hampshire, from Thursday, April 22, to Saturday, April 24, was limited to individuals and organisations within a 15-mile radius of the town, and companies and technical colleges contributed exhibits.

A typical display was provided by the apprentices of the Royal Aeronautical Establishment, Farnborough, examples of whose work in pattern-making, filing, joinery, tool-making and other trades illustrated the high quality of craftsmanship attainable in this country.

At the opening of the Exhibition, Mr. C. G. Vokes, M.I.Mech.E., who is the president of the Chamber of Commerce, said that increasingly mechanised production methods had distracted attention from the continuing need for craftsmen. Machines certainly speeded production, but someone must make the machines, and the tools with which they are equipped.

Mr. Vokes, the founder of Vokes (Air Filters) Limited, Guildford, Surrey, has played a considerable part in the promotion of these exhibitions and hopes that the example Alton is setting will be followed throughout the country, and that the movement will lead to Britain's renewed pre-eminence in the field of manufactured goods. This object will be achieved, he believes, if every worker can be persuaded to take a real pride in his own skill and ability.

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A NEW FRONTIER

The cost of eliminating air pollution from the heavily-populated industrial areas of the world will be great. If, however, the movement toward the absolute control of all air pollutants is yet another effort by mankind to secure a better environment, as part of the struggle for a better standard of living in general, then this cost will be met. That many of the problems of control defy solution by both engineer and economist is only temporary; some way will be found to meet the cost, and the technical difficulties can only be resolved by the ingenuity of engineers. These ideas were expressed and amplified by Mr. Frederick S. Mallette when he gave the James Clayton paper at the Institution of Mechanical Engineers on Friday, April 23, and extracts of which are published elsewhere in this issue. For engineers, concluded Mr. Mallette, "air-pollution control poses a tremendous challenge – it is indeed a new frontier."

He began his paper, a well-documented review of the practice of air-pollution control in the United States, with a survey of the legislation and local activity that had been accomplished in that country, where the enforcement of model ordinances has already brought about great, even dramatic, improvements in the atmosphere of some industrial areas. Probably the first ordinance of this kind was adopted in St. Louis, Missouri, in 1867, when it was enacted that "the chimneys of all manufacturing establishments be at least 20 ft. above adjoining buildings." Since that date both small and large government units have introduced legislation which has slowly changed from that aimed at no more than smoke abatement to the broader cover encompassing atmospheric pollutants of every kind.

The legislation – much of which has brought about immediate and encouraging improvements – has restricted the use of unsuitable fuels or plant and has limited the conditions under which effluents may be rejected, thereby imposing the installation of adequate cleansing plant. This has meant heavy demands for equipment of all kinds from manufacturers in the United States, ranging from small sampling apparatus for obtaining fundamental data about the problem to complete installations for controlling the effluents from the largest of power plants and factories.

In the ensuing discussion, many speakers elaborated the differences between the conditions in the United Kingdom and the United States, and went on to describe the work carried out here by the Smoke Abatement Society as well as by local authorities and individual companies. The position to-day was likened by one speaker to that when Sir Edwin Chadwick first propounded his ideas on sanitation 100 years ago. The terrible tragedies of the "smogs" suffered in Donora in the United States and in London have served to stress the real urgency of the problem. The solution will come only with effort on the part of all concerned.

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NEW IDEAS

The chief purpose of the National Research Development Corporation is to ensure that the ideas which arise in the course of research work at Government Establishments are translated into commercially practical designs.

The Corporation was founded as the result of an Act of Parliament in 1948, and in the past has achieved its purpose by receiving details from the Establishments and passing them on to a carefully selected list of firms who might be expected to be interested in the development of a particular invention. The difficulty arose, however, in that it was impossible to know precisely which firms would be interested in any given invention. This difficulty has now been overcome by a decision to publish the NRDC Bulletin, the first number of which, issued free, has been published by the Corporation from their offices at 1 Tilney-street, London, W.1. It gives a number of brief descriptions, with illustrations, of inventions made in various Establishments and Ministries, and for the development of which licences have been granted by the Corporation. An explanation is given of the terms under which licences are issued.

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SIX CARS A MINUTE

Encouraging figures for the production of cars and commercial vehicles during the first quarter of this year, have been issued by the Society of Motor Manufacturers and Traders, Limited, 148 Piccadilly, London, W.1. The figures show that output increased steadily during the three months, reaching the figure of 14,681 cars per week (or one every eleven seconds of working time) at the end of March. The corresponding figure for commercial vehicles was 4,886 per week. Totals for the quarter were 183,039 and 64,713, respectively, as against 129,176 and 61,015 in the first quarter of 1953.

A large part of this improvement was in exports and in March alone 34,416 cars were sold abroad. This was the highest figure for any month since January, 1952. 11,086 commercial vehicles were exported during the same period. The total exports for the quarter were greater by some 17,000 cars and 6,300 commercial vehicles than the 1953 figures, showing a reversal of the falling trend which has persisted since 1950. The largest single increase (14,000) was in deliveries to Australia and New Zealand, which remain the largest markets. Exports to the United States showed a decrease of 2,000, but the total to Canada was 500 greater. In Europe, an increase of over 3,000 raised the exports to Sweden to a total exceeding 8,000. Even the hotly-contested markets in Belgium, Holland and Denmark all showed an increase, while exports to the Irish Republic were nearly doubled.

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FILLING THE RANKS

Over 100 headmasters and science masters attended an "Easter School" organised by the Metropolitan-Vickers Electrical Company, Limited. The school was held at the Trafford Park works, Manchester, from April 21 to 23, and presided over by Dr. Willis Jackson, director of Research and Education, and Mr. K. R. Evans, manager of the education department. The course was designed to show what opportunities existed for engineering students of all grades, and the conferences were interspersed by tours of the works.

During the conference it was stressed that there was room for all types of apprentices for training as craftsmen, technicians or professional engineers. At one point Dr. Jackson pointed out that much of the future prosperity of this country would lie in producing goods high in "brain content" and this would mean bringing into industry a very large proportion of the best brains available in the country. Not all the possessors of these "best brains" were, or ever would be, possessors of University degrees, and firms who neglected holders of National Certificates often missed valuable men. Indeed, the degree and the certificate were complementary to each other and should be so regarded. When military service was considered, the firm always recommended that the apprenticeship should be completed first, as the trained man would almost certainly be allocated to his own trade (or to one allied to it) and would also stand a good chance of obtaining a commission which would improve his capabilities for leadership.

An apprenticeship course particularly recommended was known as the Probationary College course. Boys from secondary or public schools, who have satisfied university entrance requirements, go direct to the works for one year before entering the university. On completion of the university course, they then return for another year's apprenticeship, military service being deferred till this has been completed. This course has been found to give a very satisfactory mixing of practical and theoretical work.

For the "School Apprenticeship" course, entrants are required to hold a General Certificate of Education at Ordinary Level in four subjects or an equivalent qualification. The course lasts four years and the apprentice is expected to attend part-time classes during that period with the aim of obtaining the Higher National Certificate and eventual entry into one of the Institutions. There are also "sandwich" and trade courses to suit particular conditions. A publication of the company, *Education for Industry*, contains full details of all the schemes and describes the methods of selection.

ELECTRODEPOSITION AND METAL FINISHING

International Conference, London

Dr. J. W. Cuthbertson, assistant director of research at the Tin Research Institute and President of the Institute of Metal Finishing, 32 Great Ormond-street, London, W.C.1, occupied the chair at the first session of the fourth International Conference on Electrodeposition and Metal Finishing, held in London from April 21 to 24. The conference was opened on the first day by Brigadier A. R. W. Low, C.B.E., D.S.O., M.P., Parliamentary Secretary to the Ministry of Supply, who stated that the present fourth conference was the third to be held in London and more than 80 delegates from overseas, representing 11 countries, were present.

It was further announced during the opening proceedings that 500 persons had registered for the conference. There were 22 delegates from the United States which had acted as hosts for the second conference. The Ministry of Supply, continued Brigadier Low, were among the largest metal users in Great Britain and, indeed, in the world. The Ministry were responsible for approving the designs and for making arrangements for the supplies of all the arms, ammunition, aircraft, vehicles and equipment required by the fighting services, except for ships and their equipment. In 1953 the defence load upon the United Kingdom metal-using industries had been valued at £540 millions or about one-seventh of the total output of those industries.

There was no doubt that the work done by the conference, and that carried out by the Institute of Metal Finishing in Great Britain, by the American Electroplaters' Society in the United States, and by other similar associations overseas, would prolong the life of metals and of important equipment and might also prolong the lives of those persons who used them.

Furthermore, by utilising the art of metal finishing to the full, the surface of a metal could be invested with almost any desired properties. The result of this was that it was possible to ally with the properties of a base metal, such as cheapness, mechanical strength and "formability," a completely different set of properties belonging to a metal deposited on the surface, such as great hardness and high lustre.

After the opening ceremony the presentation and discussion of papers commenced. Eight technical sessions were held during the four days of the conference and we propose to give, in forthcoming issues, abstracts of some of the 32 papers submitted. The subjects dealt with included anodic processes; chromium, tin, nickel and other metallic deposits; and organic finishes of various types.

* * *

DIESEL ENGINE USERS ASSOCIATION

Annual Luncheon

The principal guest at the annual luncheon of the Diesel Engine Users Association, held in London on Thursday, April 15, was Professor S. J. Davies, D.Sc., Ph.D., M.I.Mech.E., Kings College, London. Immediately after the luncheon, the President, Mr. F. J. Mayor, M.I.Mar.E., A.M.I.Mech.E., presented the Percy Stilt Medal, to Mr. H. D. Adam, M.I.Mar.E., A.M.I.Mech.E., for his paper "Preventive Maintenance of Oil Engines"; an abridged version of this paper was published on page 427, in our issue of April 2, last. Following the presentation, the President proposed the toast of the guests.

Professor Davies, who proposed the toast of the Association, paid a particular tribute to the research departments of engineering manufacturers, research associations and Universities for the work they were doing, and to the Technical Press who, he said, played an important part in the dissemination of information regarding modern engineering development. He also pointed out that this country, at the present time, was only training half the men it really needed for the more advanced positions in engineering, and a recent tour, during which he had spoken to the headmasters of many of the Public schools, led him to believe that all the other professions were also demanding a bigger share of the more capable scholars. Mr. W. Howes, M.I.Mech.E., M.I.E.E., a past President of the Association proposed a vote of thanks to the President.

* * *

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION

Annual Meeting and Lunch

During recent months, a considerable expansion has taken place in the equipment and activities of the electroplating section of the British Non-Ferrous Metals Research Association, Euston-street, London, N.W.1, in order to enable the research staff to undertake a detailed study of the operation of bright nickel plating. From this it is hoped to secure means for controlling this operation more satisfactorily and improving the quality of commercial plating. In his statement as chairman of the Council of the Association at the 34th annual general meeting, held in London on April 22, Colonel the Hon. R. M. Preston, D.S.O., said that the substantial support of the motor-car industry, which had been secured during 1953, had helped materially to make this expansion possible.

Among the long-term researches of a basic character now in progress, that on the study of the properties of grain boundaries is being actively pursued. Pressure upon the staff and equipment, however, is greater for short-term investigations as these are of more immediate practical interest. Altogether some 40 investigations on copper, nickel, aluminium, magnesium, lead, tin and zinc and their alloys, and on various chemical and electrochemical finishes are under way. These are all listed in the Association's annual report for 1953 and it is only possible to mention one or two here. Further work on the mechanical and other properties of certain complex aluminium bronzes, undertaken for the Admiralty, has been concerned with the effects of composition on the tensile properties of cast alloys and on their "hardenability" on rapid cooling from high temperatures, such as occurs in welding. As emphasised by Colonel Preston in his statement, corrosion researches feature largely in the Association's programme. During 1953 a thorough survey of members' experience of steel and other materials used for tools for hot-working non-ferrous metals, particularly extrusion tools, has also been made.

At the luncheon at the Savoy Hotel which followed the annual general meeting, the toast of the Association was proposed by Sir John G. Lang, K.C.B., secretary of the Board of Admiralty. He said that the spectacular advances made in the engineering and other industries in recent years had undoubtedly been made possible by research. Although the Admiralty could not claim to have been present at the birth of the Association in 1920, the help of its staff, particularly in connection with problems of corrosion, had been available to them for many years.

In his concluding remarks Sir John referred to the approaching retirement from the chairmanship of the Council of Colonel Preston. In the course of his response to the toast of the Association, Colonel Preston said that his five years of office as chairman would come to an end on December 31, 1954, and he thanked the members and staff of the Association for their support during his period of office.

* * *

THE JUNIOR INSTITUTION OF ENGINEERS

New Headquarters in Westminster

For more than 50 years the headquarters of the Junior Institution of Engineers have been at 39 Victoria-street, Westminster, S.W.1, but for some time past the Council of the Institution have felt that more commodious premises were becoming increasingly necessary. These have now been found in Pepys House, 14 Rochester-row, S.W.1 – about five minutes' walk from the present address – and which has been acquired and is in process of redecoration. It is hoped to have the building ready for occupation by the commencement of the next session, in October.

Pepys House, a red-brick building with stone facings, was formerly the parish office of the combined parish of St. Stephen with St. John, Westminster, and takes its name from Lady Emily Pepys, a daughter of Sir Charles Christopher Pepys, Bt., Lord Chancellor of England from 1836 to 1841 and again from 1846 to 1850, who was raised to the Peerage as Earl of Cottenham on his retirement from that office. Lady Emily was an assiduous worker among the poor of the parish in the latter half of the Nineteenth Century. The building was formally opened in 1896 by Dr. Frederick Temple, the then Archbishop of Canterbury.

On the ground floor of Pepys House there is a meeting hall large enough to seat about 150, and offices for the secretary and staff. Beneath the main hall in a semi-basement is another room, of about equal size. On the first floor is a smaller room, which will house the library of the Institution, and above this is another suite of rooms, suitable for offices, which will probably be let as such if not needed for the purposes of the Institution. There is also ample accommodation on the different floors for cloak rooms, etc. The building is close to Vincent-square, which should simplify the parking of cars during meetings, and it is easily reached by bus routes Nos. 10, 11, 24, 29, 34, 39, 76 and 134. The Underground station of St. James's Park is within about seven minutes' walk.

The Junior Institution of Engineers, which began in 1884 as an association of apprentices in the Lambeth engineering works of Maudslay, Sons & Field, Limited, is the tenth oldest engineering institution in London and its membership embraces practically every branch of engineering. The present President is Sir John Hacking, M.I.E.E. Originally, it met in Lambeth, but in 1888 the venue was changed to the Westminster Palace Hotel (now Abbey House, Victoria-street), since when the ordinary meetings have always been held in or near to Victoria-street. The search for new quarters has been considerably prolonged because of the desire to continue in that district, as the recognised centre of professional engineering, and there has been much satisfaction among the members, therefore, at the successful outcome of the negotiations for the purchase of Pepys House.

OBITUARY

MR. HUBERT SCOTT-PAINE

Pioneer Aircraft Constructor and Boat Designer

We record with regret the death of Mr. H. Scott-Paine, which occurred at his home in Greenwich, Connecticut, U.S.A., on Thursday, April 15.

Hubert Scott-Paine, a pioneer aircraft constructor and air transport operator, designer and racer of high-speed motor boats, was born in Shoreham on March 11, 1891. He made his first flight in 1910, and from 1910 to 1914 designed and constructed several land-planes. In 1913, he commenced his work on marine aircraft, and constructed the first circular-section flying boat hull. From then on he patented a number of original developments in flying boats.

In 1920, he opened the first international flying-boat service between le Havre and Southampton. From 1920 until 1923, he was manager and owner of the Supermarine Aviation Works Limited, and during this period he organised and financed the construction of the Supermarine Sea Lion II, designed by R. J. Mitchell, which won the Schneider trophy contest of 1922 and thus prevented it from passing outright to Italy, who had won the two previous contests.

In 1923, Scott-Paine organised and financed the British Marine Air Navigation Company, which became merged with Imperial Airways when the latter company, of which Scott-Paine was a founder director, was formed in 1924.

From 1927 onwards, his interests turned increasingly to high-speed boat design. In 1927, he founded the British Power Boat Company Limited, of which he remained a director until his death. He designed, constructed and raced Panther I and II and Miss Britain I, II and III, and was successful in many international contests. Between 1934 and 1946 he designed and constructed the original motor torpedo boats and motor gunboats for the Royal Navy, and high-speed air/sea rescue launches for the Royal Air Force.

In 1939, he constructed patrol torpedo boats in the United States and Canada, where he set up the Marine Design and Engineering Corporation, U.S.A., and the Canadian Power Boat Company Limited; he was chairman of these two companies at the time of his death.

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MR. E. GRAHAM CLARK, C.B.E.

Secretary, The Institution of Civil Engineers

Professional engineers of all classes will learn with regret of the sudden death at Eastbourne, on Friday, April 23, of Mr. Graham Clark. Mr. Clark, who was aged 64, had served on the staff of the Institution of Civil Engineers since 1914 and had been secretary since 1937. In that capacity he was, of course, well known to a wide circle of engineers, especially for the part he had played in bringing about closer co-operation between the "Civils," "Mechanicals" and "Electricals." This association was later extended to other engineering institutions in this country, the Commonwealth, western Europe, and the United States of America, and has resulted in the creation of the Conference of Engineering Institutions of the British Commonwealth and the Conference of Representatives from the Engineering Societies of Western Europe and the United States of America.

Edmund Graham Clark was born on May 15, 1889, and was educated at Felsted School and Armstrong College, Newcastle-on-Tyne, where he obtained his Bachelor of Science degree in the University of Durham. He was then for a year in the employment of Ernest Scott and Mountain, electrical and mechanical engineers, Gateshead, and from 1911 to 1913 served as engineering assistant to Mr. J. Mitchell Moncrieff. In this capacity he was mainly engaged on work in connection with jetties, staiths and graving docks on the River Tyne.

In July, 1914, he was appointed technical and editorial assistant to the Secretary of the Institution of Civil Engineers, but holding, as he did, a commission in the Territorial Force, he was mobilised immediately on the outbreak of war. He served through the hostilities in France and Belgium and was awarded the Military Cross. At the beginning of 1919 he returned to the Institution as chief technical assistant, being appointed chief assistant in 1933 and acting secretary in May, 1937. He was confirmed in the latter position in December of the same year and was to have retired in August next.

During his long connection with the affairs of the Institution, Graham Clark had been associated specially with administrative work, although on the more technical side he had been concerned with the activities of such committees as those on the tabulation of the results of heat engine trials, reinforced concrete joints, floods and engineering quantities. As has been said, he was particularly identified with the establishment of closer relations with kindred engineering societies, as well as with representations to government on matters affecting the engineering profession.

Graham Clark was appointed a Commander of the Order of the British Empire in 1948. He was elected an Associate Member of the Institution of Civil Engineers in 1914 and transferred to the class of member in 1938. The honorary degree of Doctor of Science was conferred on him by the University of Durham last year.

We also regret to record the deaths of the following :

SIR ARTHUR WATSON, C.B.E., M.I.C.E., M.Inst.T., F.R.S.A., LL.D., J.P., at his home at Tedburn St. Mary, Exeter, Devon, on April 13, at the age of 80. He was the first general manager of the London Midland and Scottish Railway from 1923-24. In 1890 he was articled as a civil engineer to the chief engineer, Lancashire and Yorkshire Railway. He became chief assistant engineer in 1905, superintendent of the line in 1910, assistant general manager in 1918, general manager in 1919, and general manager, London and North-Western Railway, from 1921 until 1923. He was a founder member of the Institute of Transport.

MR. WILLIAM MATHEWS, at his home at Wallsend-on-Tyne on April 17, at the age of 86. Mr. Mathews was formerly pattern shop and foundry manager to the Wallsend Slipway and Engineering Company, Limited.

MR. DAVID GARFIELD RODGER, on Good Friday, April 16, during his 69th year. Mr. Rodger was assistant general manager (commercial), Johnson & Phillips Ltd., Charlton, London, S.E.7. He joined the staff of the firm in 1906 and became manager of the arc-lamp department. He was export sales manager for many years and in 1946 was made assistant general manager (commercial).

MR. WALLACE THORNEYCROFT, at his home at Chalmington, Dorchester, on April 26 at the age of 90. He was well known in the coal, iron and steel industries for a long period and served as President of the Institution of Mining Engineers from 1916 until 1918. He received his education at Charterhouse and at Owens College, Manchester, and was elected a Fellow of the Royal Society of Edinburgh some years ago.

PERSONAL

H.R.H. THE DUKE OF EDINBURGH, K.G., P.C., K.T., and AIR COMMODORE SIR FRANK WHITTLE, K.B.E., C.B., F.R.S., have been elected honorary members of the Institution of Engineering Designers, Grand Buildings, Trafalgar-square, London, W.C.2.

LIEUT.-COL. P. D. IONIDES, D.S.O., relinquished his position on the board of Babcock & Wilcox Ltd., Babcock House, Farringdon-street, London, E.C.4, on April 13, after 26 years of service. On that day SIR PERCY MILLS, Bt., K.B.E., and MR. W. F. C. SCHAAP, the company's chief engineer, were appointed to the board.

SIR HARRY PILKINGTON has been re-elected President of the Federation of British Industries, 21 Tothill-street, London, S.W.1, for a second year of office.

COLONEL SIR HAROLD SMITH, K.B.E., D.L., has joined the board of the Redheugh Iron and Steel Co. (1936) Ltd., Gateshead, Co. Durham.

REAR-ADMIRAL A. G. V. HUBBACK, C.B., C.B.E., has been appointed director of dockyards, in succession to VICE-ADMIRAL SIR YORK LA R. BEVERLEY, K.B.E., C.B., as from the end of the year. REAR-ADMIRAL J. S. C. SALTER, C.B., D.S.O., O.B.E., is to be admiral superintendent, H.M. Dockyard, Portsmouth, in succession to Rear-Admiral Hubback, as from October. REAR-ADMIRAL W. G. BRITTAIN, C.B.E., is to be flag officer, Malta, and admiral superintendent, H.M. Dockyard, Malta, in succession to Rear-Admiral Salter, as from August, 1954.

MR. H. M. MATHEWS, C.I.E., M.I.E.E., has been appointed director of engineering to the English Electric Co. Ltd., Marconi House, Strand, London, W.C.2, and is responsible for the coordination and direction of the technical policy of the company.

MR. H. G. CONWAY, M.A., F.R.Ae.S., M.I.Mech.E., has been appointed chief engineer to Short Bros. and Harland Ltd., Belfast, in succession to the late MR. A. W. S. CLARKE.

MR. R. H. S. TURNER, M.A., M.I.P.E., has been appointed works manager of the Trafford Park Works, Manchester, 17, of the Metropolitan-Vickers Electrical Co. Ltd. MR. A. PATERSON, B.Sc., A.R.T.C., A.M.I.P.E., has been made assistant works manager of these works.

MR. A. R. E. ARNOT, B.Sc. (Eng.), A.M.I.E.E., and MR. R. G. WINTON, A.M.I.Mech.E., A.M.I.P.E., have been elected to the board of Lansing Bagnall, Ltd., Kingsclere-road, Basingstoke, Hampshire. MR. H. P. MOTT, who is chairman of the Institute of Materials Handling, is joining the firm as materials and production controller.

MR. N. C. STAMFORD, M.Sc., M.I.E.E., has been appointed to the staff of the secretary of the Institution of Electrical Engineers, Savoy-place, London, W.C.2, as education officer of the Institution.

MR. L. E. MOLD, O.B.E., M.I.E.E., has retired from the board of A. Reyrolle & Co. Ltd., Hebburn-on-Tyne. He joined the company 40 years ago and has been a director for 16 years. MR. G. J. DODGSON, deputy secretary of the firm, has been appointed secretary in succession to the late MR. J. C. ARKLESS.

MR. N. R. PEACH, A.M.I.Loco.E., at present assistant divisional motive-power superintendent, Crewe, London Midland Region, British Railways, is to take up the office of district motive-power superintendent, Crewe, as from May 1, following the retirement of MR. JAMES FOSTER.

MR. R. H. GUMMER, a director of International Combustion (Holdings) Ltd., has retired from active executive duties after nearly 30 years of service, but will remain a director of the company.

The British Welding Research Association, 29, Park-cresent, London, W.1, have appointed MR. A. G. THOMPSON, B.Sc., A.M.I.C.E., to make an investigation into welding productivity.

MR. B. R. FRASER has been appointed manager at the Coryton refinery of the Vacuum Oil Co. Ltd., Caxton House, London, S.W.1, in succession to MR. D. M. GLENDINNING, who has resigned.

MR. G. W. BUSH has relinquished his connection with Renshaw Foundry Ltd., Mill Mead, Staines, Middlesex, and the management will be carried on by MR. G. K. SMITH and MR. W. T. MORTON.

MR. E. J. TOWNSEND, sales director with A. A. Jones and Shipman Ltd., Narborough-road South, Leicester, has relinquished that appointment to become the managing director of the newly-formed English subsidiary company of the Ex-Cell-O Corporation, Detroit, U.S.A., for which Messrs. Jones and Shipman have been British selling agents for some years. MR. K. H. BISHOP has been appointed general sales manager of Messrs. Jones and Shipman.

BUSINESS CHANGES

THE SCOTTISH MACHINE TOOL CORPORATION LTD., 58 Victoria-street, London, S.W.1, have opened a Birmingham and district office at 2 Sir Harry's-road, Edgbaston, Birmingham, 5. (Telephone: Calthorpe 2541.)

MATLING LTD., Wolverhampton, manufacturers of industrial trucks, have opened new offices and showrooms at 28 Caxton-street, London, S.W.1. (Telephone: ABBey 6652.)

THE PROJECTILE AND ENGINEERING CO. LTD. have formed a separate sales organisation, PECO MACHINERY SALES (WESTMINSTER) LTD., 28 Victoria-street, London, S.W.1. (Telephone, ABBey 1793-5.) MR. A. J. CHAMBERS, M.B.E., M.I.P.E., is the chairman of the new company and the other directors are MR. M. FREUND, M.I.Mech.E., and MR. E. GASPAR, A.M.I.Mech.E.

The engineering sections of the METROPOLITAN-VICKERS ELECTRICAL CO. LTD., Trafford Park, Manchester, 17, dealing with all forms of high-frequency heating as well as resistance heating, have been combined with the welding engineering department under its chief engineer, MR. C. F. SAUNDERS, to form a new heating and welding department.

In pursuance of a plan to consolidate the activities of the PARKINSON & COWAN GROUP OF COMPANIES, the electrical division of MEASUREMENTS LTD., will be transferred on April 30 to the parent company, PARKINSON & COWAN LTD. On the same date ASPEC (LONDON) LTD., will be liquidated. As from May 1, the electrical division and Aspec will be merged and will operate under the title PARKINSON AND COWAN INSTRUMENTS (INCORPORATING ASPEC) A DIVISION OF PARKINSON & COWAN LTD.

As from May 1, the name of the firm of A. LUSON & SONS LTD., Park Royal, London, N.W.10, is being changed to GEM BRUSHES (LUSON) LTD., MR. F. G. H. FOREMAN and MR. E. GROSZ, A.M.I.Mech.E. have joined the board, the latter as director in charge of research.

The ADMIRALTY GUNNERY ESTABLISHMENT moved from Teddington to Portland on April 26. The new address is: Superintendent, Admiralty Gunnery Establishment, Southwell, Portland, Dorset. (Telephone: Weymouth 1212 and 1572 and Portland 3235 and 2215.) The ADMIRALTY RESEARCH LABORATORY is remaining at Teddington, Middlesex.

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A SOCIETY OF PATTERNMAKERS

Inaugural Meeting

At a meeting held on April 8 at the Queen's Hotel, Birmingham, 33 firms from various parts of the United Kingdom were enrolled as the first founder members of the newly-formed National Society of Master Patternmakers. The list will remain open for one month, after which firms or individuals joining the Society will do so as ordinary members.

The objects and rules of the Society, as circulated on March 19, were approved and unanimously adopted, with the addition of a clause providing for the admission, at a reduced subscription, of small firms, having not more than five manual employees on their books. Briefly, the aims of the Society are to improve the status of master patternmakers and to foster the popularity and extend the usefulness of master patternshops in all parts of the United Kingdom.

Mr. B. Levy of B. Levy & Co. (Patterns) Ltd., Westminster, London, S.W.1, was elected to be the first chairman and President of the Society. In recognition of his active support in the establishment of the Society, Mr. V. C. Faulkner was elected an honorary member.

Among other suggestions for further action, it was proposed that: the Society should conduct an investigation into the establishment of British Standards for the manufacture of pattern equipment; should take action towards the drawing up of standard conditions of sale; and should make representations to national negotiating bodies on all matters affecting patternmakers. The secretaries, to whom application should be made for further particulars and membership forms, are Messrs. Mann, Judd & Co., 8 Frederick's-place, London, E.C.2.

James Clayton Paper

AIR-POLLUTION CONTROLLED

INSTRUMENTS AND PLANT

As a man-made scourge, air pollution dates back to the discovery of fire and it has probably been a nuisance ever since the advent of the use of coal towards the end of the thirteenth century. The occurrence of several major "smog" disasters in the Meuse Valley, Donora (United States), London and elsewhere have caused mankind to demand a better environment and to initiate a movement towards complete control of all air pollutants. The position as it now prevails in the United States is examined in great detail in the James Clayton paper "A New Frontier: Air-Pollution Control," by Mr. Frederick S. Mallette, M.A.S.M.E., research manager, American Society of Mechanical Engineers and executive secretary of the Society's committee on air-pollution controls. The paper was presented for discussion before the Institution of Mechanical Engineers, London, on Friday, April 23. Extracts from Mr. Mallette's paper are given below.

METEOROLOGY

An understanding of the influence which meteorological factors have upon atmospheric pollution requires a brief excursion into elementary principles. The dispersing effect of wind, turbulence and rain upon air pollution is familiar. For the present purpose, namely, that of explaining the accumulation of pollutants in specific (usually urban) areas, the most important factor is thermal differences in the air, land, and water, most of which result from differences in absorption and radiation.

As a result of these two actions, air which comes in contact with the earth's surface or with objects on it is warmed or cooled, tending to reach a temperature equilibrium with the surface over which it passes or on which it comes to rest. However, above the surface the most important influence is the process of convection which occurs as a result of temperature differences. The conditions brought about by these temperature differences owing to convection are a major factor in the accumulation or dispersal of air pollutants.

Adiabatic Changes in Temperature.—More important, especially in the development of urban smogs, is the compressibility of air. This property, which results in greater density of air near the earth because of the great mass above it, can also bring about changes in temperature through expansion and contraction. Rising air expands and is thus cooled. Descending air is compressed and is thus heated. These changes occur without transfer of heat; hence they are termed adiabatic. The dynamic cooling of dry air due to expansion is approximately 5·5 deg. F. per 1,000 feet. This rate is affected by the presence of moisture in the air which retards the cooling. The figure usually used as an average saturated adiabatic is 3·2 deg. F. per 1,000 feet.

Lapse Rates and Stability.—The previous discussion has illustrated how changes of temperature take place in ascending or descending air as a result of different pressures. They are, of course, theoretical conditions, and overlying air may not always become colder at these rates. There may be no rising or falling action, and hence no adiabatic change; there may be exchange of heat by radiation, absorption, and conduction; or there may be horizontal movements bringing warm or cold air. Therefore, the actual vertical change in temperature may be quite different from that caused by adiabatic processes.

The vertical temperature gradient, or "lapse rate" as it is more conveniently termed, is the actual change of temperature with elevation from whatever cause. The lapse rate is actually the rate at which air becomes colder with elevation; if the air gets warmer, the rate is said to be negative. "Lapse" in this connection refers to the passage from a higher to a lower temperature. When there is an increase instead of a decrease in temperature (or "inversion" as it is termed) a phenomenon most important in the causation of air pollution occurs.

Inversions may occur near the ground as a result of air cooling because of contact with the cold earth. Inversions may also exist at higher levels owing to the influx of warm winds, but the types which are layered relatively close to the earth are most effective in preventing the dispersal of air pollutants.

To return to a consideration of lapse rates, it has been found that the average value is about 3·2 deg. F. per 1,000 feet. This is approximately the same as the wet adiabatic rate, and is about the same all over the world, but varies with changes in pressure at the surface and with the changing seasons. The average lapse rate is less when the barometric pressure is low than when it is high, and less in winter than in summer.

Stability.—Lapse rates are of importance in affecting the stability of the atmosphere, and hence in the dispersal of pollutants.

Air heavier than that around it tends to fall or press downwards; if lighter than the surrounding air, it will rise. If the temperature of the air is the same for the first 1,000 ft. above the ground, air at the bottom, because it is denser, is heavier than that at the top. It tends to stay down because of its density, but, if it should be forced to rise, it would cool at the adiabatic rate. At any level, therefore, the rising portion would be heavier and cooler than the air around it. If the force which caused it to rise were removed, it would sink back to the surface. Since the air tends to return to its original position under such conditions, it is said to be stable, or in a stable equilibrium. An inversion, in which a layer of warm air lies over cold air, is an example of marked stability. Any air is stable in which the actual temperatures are higher than they would be if air rose from the surface and was cooled adiabatically. The rule may be stated: air is stable when its lapse rate is less than the adiabatic rate. Such air will stay in position or return if forced out of it. Thermal convection is not possible so long as the air remains in this condition.

To return to the part played by these phenomena in air pollution, the stable layer acts as a lid upon the area which is covered and tends to prevent the vertical dispersal of pollutants. While the layer itself is invisible, its relative resistance to penetration may be demonstrated by various means. Balloons which have been released from the ground will bounce back some distance when the inversion layer is encountered.

A further opportunity of demonstrating the location of such a layer is available at Donora. One automatic sulphur-dioxide recorder has been placed at the bottom of the valley and one each at 350 ft. and 500 ft., respectively, above the valley floor. During an inversion it is observed that the sulphur dioxide concentration is higher at the 350-ft. level than at either the 500-ft. level or the valley bottom. In other words, the various stack gases rise until they strike the inversion layer and are retained below it. It is possible on occasion to observe the smoke plume from stacks behaving in a similar manner.

It has been observed that during the Trai

Fig. 1a Before smoke control.

Fig. 1b After smoke control.

Figs. 1a and b The improvement which can be effected in the clarity of the atmosphere when smoke control is enforced is shown by these two contrasting pictures looking from Liberty Tubes towards Golden Triangle, Pittsburgh.

(British Columbia) investigation a broad isothermal layer above the main body of smoke, but below the tops of the valley sides, caused much greater surface concentrations (of gases) than were anticipated from the highly turbulent air flow in the surface layers. The valley walls probably increased the concentrations by limiting lateral diffusion, but there is reason to believe that a similar, but less marked, effect occurs over level terrain. Experience in many large towns that are not surrounded by hills supports this belief.

Smog Warnings.—Meteorological data are being used to predict both the occurrence and possible severity of smogs, with a view to controlling the situation. A smog index for Los Angeles is based upon the following: mean wind speed for 24 hours; noon visibility; noon relative humidity; departure of the 24-hour mean temperature from the long-term average for that particular day of the year; and the height, thickness, and magnitude of the temperature inversion. High values of the index indicate a smoggy day.

The investigation after the Donora smog of 1948 resulted in the recommended procedure that an alert should be issued on the approach of an extensive and slowly moving anticyclone which showed evidence of stagnating. A warning to take preventive measures should be issued when the following conditions occurred simultaneously for one day and showed no indication of improvement: stability of the valley air exceeding a specified value; valley winds of less than 5 m.p.h., and upper winds of less than 10 m.p.h.; and moderate to dense fog in the valley continuing past noon.

Statistical Analysis.—An analysis in 1951 by the Boston (Massachusetts) Weather Service of the records of meteorological observations and air sampling made at Donora, in an effort to develop a mathematical or statistical model to forecast pollution concentrations as a function of the local weather conditions. For various reasons, only part of the pollution data was used, but totalled approximately 2,300 samples taken during 1950, including gaseous sulphur dioxide, total particulate matter, and total sulphur, both gaseous and particulate, in the form of sulphate. Preliminary analysis indicated that the variations of gaseous sulphur dioxide and total particulate matter were related more systematically to the local conditions, so that only these two elements were included in the analysis.

The study indicated a number of shortcomings in the data. From this knowledge, changes were made in the manner of making observations, both atmospheric and meteorological. For one thing, a lack of continuity in the pollution record, both as to infrequency and irregularity, appeared to be a critical defect for the determination of the rates of build-up of concentrations, a process which the study disclosed could occur with more rapidity than was originally supposed to be possible. To rectify this flaw, a more systematic schedule of sampling was devised, more reliable recorders were obtained, and it was arranged for extra personnel equipped with mobile apparatus to be available during critical periods.

Prior to the analysis, the meteorological data were essentially the local observations taken at Donora and at the United States Weather Bureau station at the Pittsburgh Airport. In addition, the Boston Weather Service prepared a complete set of surface and upper-level weather maps. The principal inadequacies in these data were found to have their origins in the distance between the Weather Bureau's airport station and Donora – a matter of approximately 12 miles – which made the accurate determination of local stability and wind-shear conditions in the valley over Donora quite uncertain, and in the infrequency of recorded accurate temperature observations at Donora, which made possible only infrequent determination of the vertical lapse rate.

The inadequacy of the airport data was later accentuated by the moving of the weather station to the new City-County Airport, located about 15 miles north-west of the city and about 27 miles from Donora. This defect was remedied by installing a weather observation tower at the top of the Donora valley.

Influencing Factors.—As might be expected, the meteorological factors which influenced the pollution at Donora were wind direction and speed, but especially the interaction effect found to exist between winds at the bottom and at the top of the valley; the vertical temperature lapse rate, though here the dependence of the contamination was not always uniform, being also dependent on the values of the other weather elements; and wind shear. In this instance, wind shear is defined as the angular difference between the wind at Donora and at the airport, having a range of values between 0 and 180 deg. All instances of high concentration of solids and sulphur dioxide were found to occur with a large shear. However, again there was found to be interdependence of all weather elements, since all instances of large shear did not show high pollution concentrations. When they did, the occurrence was in specific quadrants, especially between 90 and 190 deg. (south-east quadrant) at the airport and between 270 and 360 deg. (nort-west quadrant) at Donora. This tendency evidently explains the interaction effect noted above. No other meteorological parameters, such as temperature, humidity, or a combination of local wind conditions and specific sources of pollution, showed any correlation with the variability of the pollution.

The result of the analysis was that, in terms of the meteorological factors, only about one-half of the variability of the sulphur-dioxide contamination could be accounted for by an objective statistical-prediction model. It was thought that this percentage could be considerably improved, especially for the critical high concentrations. The indications were that effort should be applied to increase the accuracy of pollution measurements, to achieve reliable wind velocity and temperature determinations (from the tower aforementioned), and to increase the frequency of weather and pollution observations, for it was found that fluctuations of the preceding three or four hours often had more to do with a high concentration than did changes of the preceding 24 hours.

INSTRUMENT DEVELOPMENT

Industrial Hygiene.—One great advantage available to those faced with the study of air-pollution problems in the United States is the advanced development of industrial-hygiene instruments and techniques. Industrial hygiene, which is the study and control of health hazards in the air of industrial plants, had available an enormous selection of instrumental methods which required only slight modification to be used for atmospheric studies. When the new problem arose, many industrial hygiene specialists applied their sampling and analytical experience to meeting the demands of air pollution. Most of those specialists were better equipped by training and experience to deal with the complex range of air pollutants than were those who possessed only a background of experience in the control of smoke and fly-ash. The improvements which have been effected in those parts of the United States where adequate controls have been imposed is illustrated in the two contrasting pictures in Figs. 1a and 1b, on this page.

For the full investigation of the Donora Smog of 1948 trained specialists in industrial hygiene brought to the problem instrumental methods and analytical techniques which could quickly give a picture of the atmospheric contaminants. Many of the instruments primarily developed for industrial-hygiene problems are commercially available, such as the Green-Smith standard and midget impingers for the collection of particulate matter and soluble gases and vapours. Another useful tool is the electrostatic-precipitator sampler shown in Fig. 2, opposite, and designed for the collection of extremely fine aerosols.

Dust-fall (*Grit*).—No universal standardisation exists for the collection of dust-fall by jars (deposit gauges). Most workers have some particular type of collection equipment which they have found best serves their needs and for this reason it is difficult to compare results taken by the various techniques available. In any event, there are sizeable variations (two to one and greater) in samples collected even within relatively short distances of each other. Therefore, only the aggregate of a large number of samplings has any real significance as a measure of the dust settling. It does appear that the best results are obtained by the use of jars with wet bottoms (permanent anti-freeze solution) in clusters of three, placed 3 or 4 ft. above the roof or other surface. It is also desirable to determine the characteristic percentage of water-soluble matter for a particular town or location, which has rarely been found to exceed 10 to 15 per cent. Thereafter, all insoluble residue values can be corrected by the use of this factor.

It would also appear that, because of the large variations in different areas of a community, it is quite meaningless to report the total dust-fall or the average dust-fall for a large town. It is therefore impossible accurately to compare different towns by taking averages of all the dust-fall measurements in each. A useful classification of data may be based upon the type of neighbourhood where collection is made. The following classifications are suggested:—

Class A, suburban or agricultural;

Class B, town residential (relatively remote from industrial areas);

Class C, residential, adjacent to industrial (including commercial) districts; and

Class D, industrial (few residences).

By using these classifications, while keeping in mind their limitations, and by using seasons of the year (since a given month has no particular significance), it is possible to obtain figures of a consistent character as in Table 1.

A new development in automatic dust-fall collection is the directional apparatus with separate jars for each of the eight points of the

compass, with a ninth centre jar for calm air. However, it is doubtful whether a sufficient number of these devices have been used to provide for adequate estimation, and no published results based upon them have appeared.

TABLE I.—CHARACTERISTIC DUST-FALL IN AMERICAN TOWNS, TONS PER SQUARE MILE PER MONTH

Class of District	Winter	Summer
Suburban	10–20	5–15
Town residential	20–60	10–30
Near industrial	20–125	15–60
Industrial	(Extreme range)	

Smoke.—All of the above refers only to atmospheric particulate matter which settles readily. There is, in addition, the much finer matter which may be referred to under the collective term of "smoke," and which has as its principal nuisance effect the soiling of walls, ceilings, and other surfaces.

The instrument developed for this purpose during the American Iron and Steel Institute's research project is of particular interest because it is now commercially available. It is relatively inexpensive, so that a number of devices may be utilised without excessive cost, and its basic design has been adapted to the sampling of hydrogen sulphide. The apparatus makes it possible to compare concentrations of smoke in different locations, to trace automatically the variations in smoke concentrations with time, and to produce a historical record of monthly average concentrations (comparable to monthly dust-fall records).

These finer particles or aerosols may also be collected by the various forms of the electrostatic precipitator, by the thermal precipitator, or by the cascade impactor. A continuous electrostatic precipitator has been developed in which the aerosol is captured on a rotating stainless-steel disc which dips into flowing water. This device may be used for any aerosol which yields an electrolyte.

A smoke-concentration indicating meter based upon the scatter of light by particles in the atmosphere is also commercially available. Apparatus for photographing the forward scattered light and other devices based upon the same principle or on the absorption of light have also been constructed.

The "Autosampler" is completely automatic, collecting hourly samples of air at the rate of 25 to 40 cub. ft. per minute in the form of a spot on filter paper, and also a weighable sample on an asbestos pad. The spots are measured by reflection and by reference to the weighed samples. The reflection was found to be a linear function of the weighed deposit until the reflected value was reduced to 60 per cent.

Fig. 2 Setting up an electrostatic precipitator for sampling atmospheric dusts, fumes and other extremely fine aerosols.

Extremely fine-pore plastic "molecular-filter" substances have been developed which are most useful in air sampling. Their air-flow resistance is low and the pore size very small. However, they are not resistant to high temperatures.

Increasing dissatisfaction with the Ringelmann chart for the measurement of smoke density, though it is still in force in most ordinances, has stimulated the development of a number of devices which attempt to reduce the causes of error and offer simplified checking. Among these are the "Umbrascope" (in the Cincinnati, Ohio, ordinance), the "Smokescope," and a photo-engraved chart wherein dots will fuse visually at a minimum distance of 20 in. from the observer's eye. This latter device is suggested by the New York City Department of Air Pollution Control.

For obtaining large samples of particulate matter, the high volume sampler may be used. To obtain samples of fly-ash, various designs based upon the cyclone may be used. One model, the "Aerotec," is commercially available.

The A.S.M.E. Power Test Code for stack sampling is still widely used, but a number of modifications recently published indicate the need for a somewhat simpler procedure.

No strikingly new stack-sampling instruments have appeared, but Fig. 3, herewith, shows an interesting device which was developed during the course of research at Mellon Institute. The motor mounted on the tripod raises and lowers the manifold continuously for complete coverage of the total cross-section of a horizontal flue, for example, a boiler breeching, represented in the illustration by the scaffolding. The use of the unconventional manifolding arrangement was found to be possible by the discovery that appreciable departure from iso-kinetic velocities is permissible if the size of gas samples is based upon stack velocity instead of on sampling-tube velocity.

For the study of sulphur dioxide, in addition to the established methods, there are available two commercial recorders which have the principal disadvantage of relatively high cost. The first is the Leeds and Northrup sulphur dioxide autometer based upon the Thomas conductivity method which presents a record of relatively "instantaneous" periods of average concentrations of 1 to 2 minutes. An accumulating type has also been developed which registers not only the total change of conductivity during such period of, for example, 30 minutes, but also differences of concentration during the sampling interval. This latter type may also be used for hydrogen fluoride after minor modification.

The second instrument for sulphur dioxide is the "Titrilog" which absorbs the gas in dilute bromine solution. The current required to release the bromine is recorded and serves as a measure of the sulphur dioxide. This device has one advantage over the autometer in that it is available in a portable model. Neither instrument is completely specific for sulphur dioxide, but they are sufficiently accurate for most air-pollution studies.

To study the complex mixture of gases in the Los Angeles area, various methods have been used, including continuous analysis of the "oxidising" properties of the atmosphere, freezing out air samples by a special collecting train, and analysis of combustion or by the infra-red or mass spectrograph. The Stanford Research Institute has designed and constructed "oxidant" recorders based upon the liberation of iodine from potassium iodide, which can be placed in various locations. This permits correlation with other smog characteristics. Further study has disclosed that the "oxidant" is, in fact, ozone.

The need for better micro-meteorological data has brought about desirable modifications in the traditional weather instruments. The aerovane, used in conjunction with the mobile laboratory shown in Fig. 4, on page 552, by providing both wind direction and velocity, can replace the wind vane and bridled cup anemometer. The aerovane is essentially a small-voltage generator which creates a voltage proportional to the wind speed; wind direction is transmitted to the recorder by Selsyn motors, with an arrangement at the receiving end which permits the recording pen to move back and forth across the chart in a limited arc, representing 540 deg.

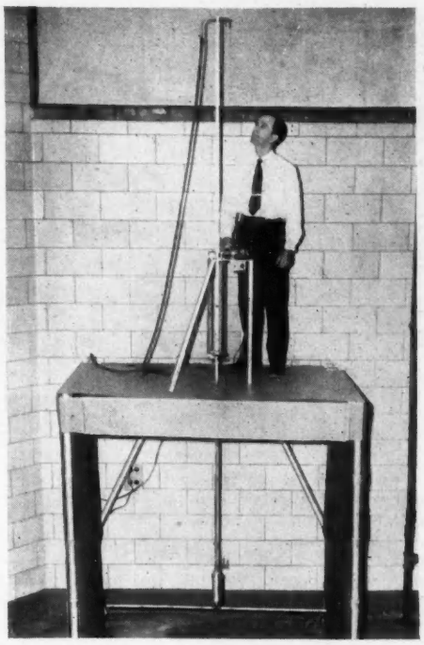

Fig. 3 An automatic traversing sampler for horizontal flues as, for example, a boiler breeching. A motor is used to raise and lower the manifold continuously so that samples are obtained from the full cross-section.

An elaborate installation for measuring the stability of the atmosphere has been built at the Brookhaven National Laboratory, where a tower 400 ft. high supports the instruments and provides means of releasing smoke streams at various elevations. Measurements of air temperature, wind direction, and velocity, at seven levels on the tower, provide the meteorological data for the weather forecast by which the Brookhaven atomic pile is operated.

CONTROL EQUIPMENT

The tremendous activity in air-pollution control has resulted in a field day for the equipment manufacturers, but it has caused many problems. New and stringent requirements have entailed a huge task of research and development before the equipment can be built. All of the traditional control methods have been utilised to the utmost, and new ones have been developed, tested, and in many instances found to be satisfactory. With restrictions on the weight, appearance, and chemical characteristics of pollutants, extensive engineering studies are often necessary before successful solutions to control problems can be found.

Steel Industry Control Problems.—An example of the pollution problems which are now commonplace is presented by the steel open-hearth furnace. In practically every instance where control of its dense fumes has been attempted, thorough research preceded the design and yet, after installation of the equipment, many changes have had to be made before official agencies would approve the result.

Although dry and wet collectors, sonic agglomerators, cloth, plastic, and pebble filters have been tried for control of pollutants from open-hearth furnaces, the only satisfactory installa-

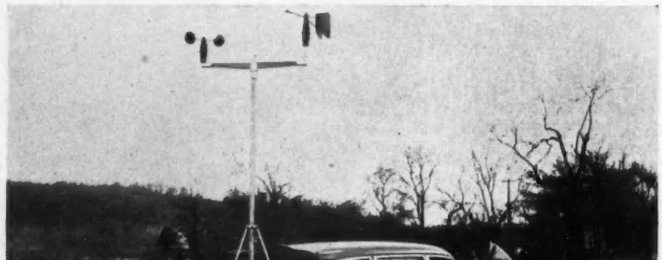

Fig. 4 A mobile laboratory used for studying atmospheric pollution and meteorological conditions. The aerovane provides information on both wind direction and velocity so replacing the independent wind vane and bridled-cup anemometer.

tions known to the author are equipped with electrostatic precipitators. In one particular instance, control of fumes and dust from four 58-ton cold-metal furnaces was required. Engineering studies resulted in the installation of dry-plate electrostatic precipitators preceded by waste-heat boilers. The deciding factors were the extreme fineness of the dust and fume, the corrosive nature of wet open-hearth-furnace gas, a limited water supply, and the high temperature of the gases.

However, the cost of adequate control is high. Preliminary studies indicate that for the average 250-ton open-hearth furnace, the installation of an electrostatic-precipitation control system costs approximately half-a-million dollars.

Power Industry Problems.—In the power industry, mechanical collectors are frequently placed ahead of electrostatic units, since this assures an efficiency of at least 80 per cent. before the gas enters the precipitators. The resulting pressure drop, which must be compensated for, may be troublesome in old plants, but in new installations provision can be made for it in the fan design. The requirements of new ordinances are particularly hard on old plants because of the high cost and frequent lack of available space for equipment.

A new development in the mechanical-collector field is the " Aerodyne," which is quite different. Illustrated in Fig. 5, below, it provides a collection efficiency of 80 per cent. with a pressure drop of only 1 in. In order to improve the performance of old precipitators, a large utility company has installed Aerodyne units on two 1,000,000-lb. per hour boilers, one 900,000-lb. per hour boiler, and two 500,000-lb. per hour boilers.

As to the control of sulphur dioxide in industrial stack-gases, British experience at Battersea, Fulham, and Swansea power stations has indicated the enormous difficulties to be surmounted. The only thing to be said here is that, at the moment, no economical and practical solution for the reduction of sulphur dioxide has even been suggested. The eventual depletion of world supplies of sulphur may result in a solution, while the production of ammonium sulphate, as at the Trail (British Columbia) smelters, may also provide one. However, it is a problem which eventually will have to be faced, for on present evidence it seems to constitute an important air-pollution factor.

Chemical Industry Problem.—The solution of the air-pollution problem arising from the use of air-blown sulphuric acid concentrators is an example of the attitude which the chemical industry has taken. The effluent from such concentrators contains acid mist and sulphur dioxide. Attempts were made to control the acid mist with low-pressure sprays, bag filters, and an acid-fume furnace, but the only successful method found was a high-pressure water-fog system. In a pilot model, mist-removal efficiencies as high as 95 per cent. were achieved at a spray pressure of 500 lb. and a water rate of 6 gal. per minute.

A plant-scale unit was put in service and, when operating at design conditions, gave even an increase in efficiency over the pilot model. The water used was 4·5 gallon per minute per 1,000 cub. ft. of gas at flow conditions. The value of sulphuric acid recovered, based on the cost of sulphur saved, and of the heat saving, by recovery of sensible heat from the waste gases, amounts to 55,000 dollars per unit a year. The net operating cost is 5,000 dollars a year and amounts to only two cents per ton of acid concentrated for the process concerned.

Rubber Industry Problems.—In both the synthetic-rubber and the reclaimed-rubber processes, drying operations are necessary to drive off excess moisture. The application of heat drives off the volatile compounds present, resulting in odour problems and, with the reclaimed rubber, in the release of an eye and respiratory-tract irriant from the softeners used.

A pilot model of a catalytic-oxidation unit was tried with excellent removal of the odourous and irritating compounds. The synthetic rubber dryers have a relatively low output of gases, so that this method can provide a satisfactory solution which is not excessive in cost. However, the large volumes of gas from the reclaim dryers would require enormous oxidation units and the cost would be very high.

For that reason, two-stage wet scrubbers are being used with good results. Water shortage and inadequate sewerage have forced the use of a recirculating system which in the experimental stage seems to hold promise. However, every control system utilising water must eventually face the water-pollution abatement programme, which, in the United States, is as restrictive as the enforcement of elimination of atmospheric contamination.

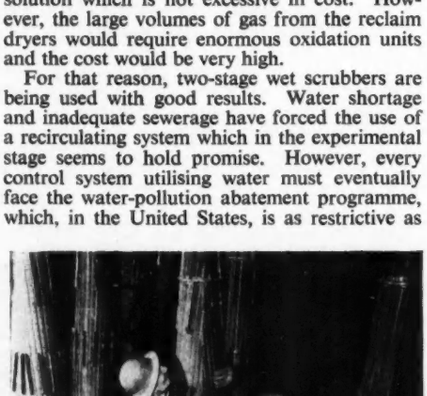

Fig. 5 The " Aerodyne " is a new development among mechanical collectors and is claimed to give a collection efficiency of 80 per cent. with a pressure drop of only 1 in.

As a new development, catalytic oxidation is receiving increased attention for application in gas, vapour, and smoke problems. It has been used successfully for eliminating solvent vapours in the metal-decorating industry, for controlling smoke and odours from incinerators and from coffee roasting, for destroying effluent from wire-enamelling ovens, and for dealing with tail gases in the manufacture of phthalic anhydride, exhaust gases from a gas-fired dryer on a high-speed printing press, and fumes from the cooking of resins and varnishes. Many of these units are self-sustaining after preheating, depending on the energy content of the gases to be consumed. If excessive amounts of auxiliary heat have to be supplied, the catalytic-oxidation principle loses its attraction.

SOCIO-ECONOMIC CONSIDERATIONS

Air-pollution-control activity in the United States has varied considerably. Before 1930, attention was focused principally on isolated problems. During the early 1930's there was a period of very little effort owing to the decreased industrial-production level of the years of depression.

An active period of control effort began late in the 1930's, but was interrupted by the second world war, and was then resumed again after the armistice. But it was not until the occurrence of the Donora Smog in 1948 that public interest in air pollution in the United States became widespread. This interest was deepened by the enormity of the disasters caused in London by smog, which by its very magnitude seemed almost incredible.

It is reported that almost 50 of the leading universities, colleges and institutes are devoting time and effort to research on air-pollution problems. The cost of this technical endeavour runs into millions of dollars a year. All this activity is evidence of man's effort to secure a better environment. Just as the demands were met for better food and water, better clothing, better housing, and a better standard of living in general, so too will be the demand for a better atmosphere. Air and steam pollution-control programmes are moving ahead at practically the same pace, and it is not improbable that the day will come when neither the atmosphere nor the streams may be used as sewers.

The cost will be truly staggering, but man never balks at the price of progress. Not all of this future betterment will be as easily accomplished as it is imagined. Many of the problems at present defy efforts at control, either from an engineering or an economic point of view. Some way will be found to meet the cost, but the technical difficulties can only be solved by the ingenuity of engineers. For them, air-pollution control poses a tremendous challenge – it is indeed a new frontier.

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UNITED KINGDOM IRON AND STEEL PRODUCTION

Record Outputs

Statistics issued by the Iron and Steel Board, Norfolk House, St. James's-square, London, S.W.1, show that steel production in March averaged 364,800 tons a week. This exceeds the previous record of 363,000 tons a week achieved in November, 1953, and compares with a weekly average of 351,400 tons for March, 1953. The annual rate for last month was 18,969,000 tons, against 18,272,000 tons for March, 1953, and for the first quarter of the present year, 18,777,000 tons, compared with 18,207,000 tons for the first quarter of 1953.

The output of pig iron averaged 230,900 tons a week in March, 1954, which is 1,300 tons a week higher than the average for January this year, the previous best month. The annual rate for March, 1954, was 12,007,000 tons, against 11,941,000 tons for January, 1954, and for the first quarter of this year 11,848,000 tons, compared with 11,152,000 tons for the first quarter of 1953.

BOOK REVIEWS

Ceramics: A Symposium. Arranged and edited by A. T. GREEN and GERALD H. STEWART. *The British Ceramic Society, Queen's-road, Penkhull, Stoke-on-Trent.* (65*s.* to non members; 45*s.* to members.)

In recent years a considerable amount of work has been done on mixtures of ceramics and metals, or "cermets," and on high-temperature ceramic coatings for metals. The research has been inspired by the development of gas turbines, which have created a need for components combining resistance to high temperature and chemical attack with adequate tensile strength. There are also many other uses of ceramics in engineering. The symposium which has been published recently by the British Ceramic Society is therefore of interest to engineers. It is a report of progress. The Society is relatively young – it was formed in 1900 – and the decision to publish a symposium was made during their jubilee year. The book has three sections, covering pottery, refractories and heavy-clay wares, corresponding to the three sections of the Society, and a general or scientific section. More than 30 scientists have contributed to the 870 pages.

The chapters on refractories alone occupy more than 300 pages, for they cover a wide field. Dr. W. A. Archibald and Mr. E. J. D. Smith, writing on "Super Refractories," point out that many of the carbides, sulphides, silicides and borides have been added to the lists of potential high-temperature refractories. They describe the work on alumina, magnesia, zirconia, thoria and beryllia. Their explanation of the properties of these pure oxide refractories is helped by a comprehensive table of values. Progress with fireclay brick and other heavy refractories for the iron and steel industry is covered by several contributors. Mr. F. H. Clews covers the fireclay brick and other alumino-silicate refractories which have so many uses in the melting and heat-treatment of ferrous and non-ferrous metals. Dr. J. H. Chesters discusses fireclay, silica, chrome, magnesite and dolomite refractories for steel production and draws attention to the value of co-operation between the manufacturer of refractories, the user and the furnace designer as a three-party team. Mr. J. MacKenzie describes progress with refractories for blast furnaces, showing how co-operation between the manufacturers of refractories and the smelters of iron has resulted in the successful adoption of carbon blocks for blast-furnace hearths.

A chapter of interest in another field is by Mr. J. Laming, who gives the story of refractories for the gas industry from 1900 to 1950. He deals with the horizontal, intermittent vertical and continuous vertical retorts. Discussing the problem of scurfing and flaking of silica shapes in the central zones of continuous vertical retorts, he indicates that recent investigations in the laboratory may help to provide a solution. Furnace engineers will note the chapter by Mr. H. Oliver, who writes on insulating bricks for furnace construction. After referring to the use of diatomaceous brick and other medium-temperature materials for the prevention of loss of heat through walls, he describes the development of hot-face or lightweight refractories of low heat capacity for reducing heat storage within the furnace structure. He explains several methods of securing high porosity in refractories during manufacture, and concludes with the view that during the next decade we may have a wide range of heat-insulation materials which the furnace designer can incorporate in furnace structures to obtain optimum economy in operation.

Mr. E. C. Bloor writes on the composition and properties of electrical ceramics. He describes the manufacture and the properties of porcelain, cordierite, steatite, zircon and titania bodies, and includes a useful table of properties and a list of definitions, electrical and physical. The references to electronic signal devices, radio, radar, television, hearing aids and high-frequency insulation show how modern needs have caused the development of a new range of ceramics.

The heavy-clay wares section of the symposium contains a competent survey by Mr. B. Butterworth. Commenting on the history of clay building materials, he considers that the beginnings of our knowledge belong not to ceramics but to engineering. The Building Materials section of the British Ceramic Society was formed in 1928. Mr. Butterworth discusses the three main classes of building brick – common, facing and engineering – and the two main classes of roofing tile – plain and single lap. He describes the tests for determining hardness, mechanical strength, soluble salt content, efflorescence, permeability and resistance to frost, and reminds us that lightweight and hollow bricks which provide better heat insulation than normal dense bricks are worse, and not better, sound insulators. Forecasting the direction of work on clay building materials, he suggests that an increase in size and a reduction in density and strength of building units is inevitable.

Those who associate the Potteries with bottle kilns showing on the skyline will be surprised to learn of the number and variety of tunnel kilns installed during the last twenty years. A contribution by Mr. A. Dinsdale in the pottery section describes the application of engineering and flow-through principles to pottery manufacture. Photographs illustrate the open setting of pottery on kiln cars and the reduced use of saggars with consequent increase of pay load in the kiln throughput.

In the general section of the book Dr. G. W. Brindley and Mr. D. M. C. MacEwan write on the structural aspects of the mineralogy of clay and related silicates; Dr. James White discusses phase relationships and ionic bonding; Mr. H. M. Richardson reviews the use of X-rays in the study of ceramics; and Dr. J. F. Hyslop describes the action of heat on clays. Ceramists will observe some omissions from the book and will consider that space might have been given to refractories for the glass and non-ferrous metal industries. A detailed index would have been useful. Engineers, however, should welcome the book. They will agree with the President of the British Ceramic Society, Dr. A. T. Green, who in a foreword describes the symposium as a worthwhile contribution to the literature of Ceramics.

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TRADE PUBLICATIONS

Electric Clocks. We have received an illustrated catalogue from Gent and Co., Ltd., Faraday Works, Leicester, showing their range of electric clocks, which can be operated either from the mains supply or by an impulse from a master clock. The impulse-type clocks are accurate to within ½-second per day.

Mixing Machines. An extensive range of mixing machines for pastes, powders and liquids of all viscosities are described in a series of illustrated leaflets issued by Steele and Cowlishaw, Ltd., Cooper-street, Hanley, Stoke-on-Trent, Staffordshire. Paints, lacquers, rubber-solution, earths, chemicals, toothpaste and products used in the artificial silk, wallpaper and linoleum industries are among the substances dealt with by these machines which are made in horizontal and vertical form. Motor-driven and belt-driven versions of most models are available and a small hand mixer is also built.

Abrasive-Wheel Cutting-off Machine. In a leaflet published by Francis W. Birkett & Sons, Ltd., Cleckheaton, Yorkshire, is described a high-speed abrasive-wheel cutting-off machine, which is capable of cutting brass, gun-metal, phosphor bronze, and steel bar up to 2 in. in diameter. The "Franbar" cutting tool can penetrate to a maximum depth of 4 in. and incorporates a rise-and-fall spindle.

Process Pumps. A range of single and multi-stage centrifugal process pumps are listed, together with details of performance, in a pamphlet issued by Sigmund Pumps, Ltd., Terminal House, 52 Grosvenor-gardens, London, S.W.1. Pressures developed by the pumps range from 150 lb. per sq. in. to 2,200 lb. per sq. in. Pumping rates up to 6,500 gals. per min. may be obtained and certain models can operate at a temperature of 900 deg. F. Examples of installations are shown in a further booklet.

Wood Refuse Collection. An illustrated booklet showing examples of wood-refuse collection installations and describing the separate items of plant from which they are built has been published by the Sturtevant Engineering Co., Ltd., Southern House, Cannon-street, London, E.C.4. The relative merits of cyclone collectors and textile-sleeve filters for the collection of chips, shavings and sanding dust are discussed.

Car Parking Meters. Venner, Ltd., Kingston-bypass, New Malden, Surrey, have issued a number of leaflets showing plans for car parks using their Park-O-Meter. This instrument, similar to the parking meters used in the United States, consists of a coin box and a seven-day clock mechanism which is automatically operated by inserting the appropriate coin. A pointer indicates the parking time available in proportion to the amount inserted. When the time has expired a red marker appears beneath the dial. In the United States a police officer patrols the parking area and issues fines to owners who leave their vehicle on the park after the period has expired.

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BOOKS RECEIVED

Non-Ferrous Heavy Metal Fabrication in the U.S.A. Technical Assistance Mission No. 79. *Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris 16e*; and *H.M. Stationery Office, Kingsway, London, W.C.2.* (16*s.*)

Tables of Lagrangian Coefficients for Sexagesimal Interpolation. U.S. National Bureau of Standards Applied Mathematics Series No. 35. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (2 dols.)

Mechanical Testing of Metallic Materials with Special Reference to Proof Stress. By R. A. BEAUMONT. *Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2.* (25*s.*)

Reports of the College of Aeronautics, Cranfield:

No. 66: Testing and Analysis of a 60 deg. Swept Back Wing with Ribs Parallel to the Line of Flight. By D. HOWE. (5*s.*)

No. 77: Estimation of the Effects of Distortion on the Longitudinal Stability of Swept Wing Aircraft at High Speeds (Sub-Critical Mach Numbers). By B. S. CAMPION. (5*s.*)

No. 78: Stress Concentration in Swept Wing Panels Using Photoelastic Models. By G. M. COILEY. (5*s.*)

The Librarian, The College of Aeronautics, Cranfield, Buckinghamshire.

Beam Formulas. By A. KLEINLOGEL. *Crosby Lockwood and Son, Limited, 39 Thurloe-street, London, S.W.7.* (40*s.*)

The Home Workshop. Planning, Wiring, Selection and Maintenance of Power and Hand Tools. By WILLIAM R. WELLMAN. *D. Van Nostrand Company, Incorporated, 250 Fourth-avenue, New York 3, N.Y., U.S.A.*; and *Macmillan and Company, Limited, St. Martin's-street, London, W.C.2.* (27*s.*)

Automotive Mechanics. By JOSEPH HEITNER. *D. Van Nostrand Company, Incorporated, 250 Fourth-avenue, New York 3, N.Y., U.S.A.*; and *Macmillan and Company, Limited, St. Martin's-street, London, W.C.2.* (45*s.*)

Water Pollution Research, 1953. Report of the Water Pollution Research Board. *H.M. Stationery Office, Kingsway, London, W.C.2.* (2*s.* 6*d.*)

Projection Welding of Mild Steel. *British Welding Research Association, 29 Park-crescent, London, W.1.* (3*s.* 6*d.*)

A Study of Single-Sized Gravel Aggregates for Roadmaking. Road Research Technical Paper No. 30. *H.M. Stationery Office, Kingsway, London, W.C.2.* (1*s.*)

Characteristics and Applications of Resistance Strain Gages. U.S. National Bureau of Standards Circular 528. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (1·50 dols.)

Table of Secants and Cosecants to Nine Significant Figures at Hundredths of a Degree. U.S. National Bureau of Standards Applied Mathematics Series No. 40. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (35 cents.)

Wärmespannungen infolge stationärer Temperaturfelder. By E. MELAN and H. PARKUS. *Springer-Verlag in Wien 1, Molkerbastei 5.* (31*s.* 6*d.*)

The Institution of Naval Architects (*continued from page* 523)

DESIGN OF LARGE TRAWLERS

THE FISH FACTORY SHIP

Sir Charles S. Lillicrap, K.C.B., took the chair at the second session, on the morning of April 8, of the Spring Meeting of the Institution of Naval Architects, when two papers were presented. These were "A Note on Large Trawlers," by Professor Ir. H. E. Jaeger, and "Underwater Television," by Lieut.-Commander J. N. Bathurst, O.B.E., D.S.C., R.N. The latter paper was presented jointly to the Institution and the Institute of Marine Engineers. A summary of Professor Jaeger's paper is given below.

Professor Jaeger, who holds the chair of naval architecture at the Technical University, Delft, considered in his paper the design of trawlers of between 165 and 185 ft. in length, with displacements of between 1,000 and 1,300 tons, such as are used in the waters off Iceland and Newfoundland. Essential features of such vessels, he indicated, were a large radius of action, high speed, good sea-keeping qualities, a low freeboard, and a large deck-surface. Diesel propulsion was usual because of the long distances to be covered, as fishing at 2,000 miles from the home port involved three to four weeks at sea, of which only ten days would be spent in fishing; but German owners were still developing steam power. Modern designers favoured a raised quarterdeck as giving better crew spaces, more room on the working deck, a better position for the steersman, and a greater freeboard from the stability point of view without too much at the working deck. Maximum draught aft would not exceed 9·5 per cent. of the length, and the propeller immersion would be about 4 ft. 6 in. The metacentric height must not be less than 2 ft. in the most severe operating condition, and must be checked on the fishing ground by noting the period of roll, as every catch added to the difficulty of maintaining sufficient stability, especially in the case of steam vessels.

VARIABLE-PITCH PROPELLER

Model experiments for determining propeller dimensions were always made for "en route" open-sea conditions. Propellers were of large diameter because, when fishing, the propeller was pulling the trawl at only 3½ to 4 knots, and was absorbing only a fraction of the full-speed power. That problem might be met by using part of the propelling power to drive the trawl winch, or by fitting a controllable-pitch propeller; the latter solution had many advantages. The combination of the two solutions, Professor Jaeger added, was a possibility which appeared to be economically attractive. At full load, the efficiency of a controllable-pitch propeller would be about 4 per cent. less than that of a normal propeller, but there were compensating advantages under all other conditions. The fuel consumption of a trawler when fishing was difficult to calculate, but appeared to be between 80 and 85 per cent. of that in the free-running condition.

In conclusion, Professor Jaeger discussed the design of fish holds and the conservation of the fish. Refrigeration might be by means of ice, by mechanical cooling, or by a combination of the two systems. It had been found that fish holds of about 17,700 cub. ft. capacity were the most effective; such a hold would be filled in 10 to 11 days, assuming a catch of 25 to 30 tons a day. Many owners preferred ice-cooling, as being the more rapid method, but the only way to ensure that a catch from Iceland or Newfoundland waters would reach the home port in a "fresh" condition was the adoption of deep freezing. The paper concluded with a description of a design for a fish factory ship, to conserve fish fillets at very low temperature, treating the catch at the rate of 25 tons a day during 60 days fishing. The designed displacement, fully loaded, was 2,400 tons and she would return carrying 500 tons of fish fillets, 300 tons of fish meal, and 35 tons of cod-liver oil; but the successful use of such a vessel would require a considerable organisation on shore. On the other hand, one vessel of the type described might well replace six or seven normal big trawlers.

DISCUSSION

The discussion was opened by Mr. de Rooij, who referred particularly to the controllable-pitch propeller and the application of light-alloy constructions. He had found, during five years' experience with that sort of propeller, that the ships' officers were inclined to alter the pitch of the propeller too frequently and too quickly. In the case of trawlers, there was the possibility that the fishing nets and hawsers might foul the propeller, which was always turning at the same speed. On the Dutch pilot vessels, of about the same dimensions as trawlers and fitted with the same type of variable-pitch propellers, the loss of efficiency experienced at full load was about 8 or 9 per cent., compared with the optimum propeller, or double the amount mentioned in the paper. Because of the construction, special attention should be given to the after bearing in the stern tube and to the diameter of the shaft, the bending moment being much bigger than with the normal propeller. Probably this was the reason why, at first, there had been rather much oil leakage from the stern tube through the Cedervall stern gland. One advantage claimed for the controlled-pitch propeller was that the towing speed was greater. That advantage was doubtful; at a speed greater than five knots, the nets would not stand the strain. When light-alloy construction was used for the fish holds, did the slime of the fish cause any chemical reaction with the metal? And could the author indicate the best kind of glue to use for connecting cork slabs or Isoflex directly to aluminium sheets?

Mr. de Rooij considered the Diesel-electric system to be ideal for such a big deep-freeze trawler as that mentioned in the paper, having a loaded displacement of 2,400 tons, and propelled by a 1,400 brake horse-power Diesel motor, especially as there were many auxiliaries, such as heavy trawl winches, the cooling system, filleting installations, fishmeal mills, etc. Diesel-electric propulsion was not cheap; but a controllable-pitch propeller for about 1,400 brake horse-power was also very expensive. The factory ship project shown had not the typical silhouette of a trawler, and he thought the ratio of lateral surface to the surface of the ship above the load line was not so favourable as with the older types. Was that not dangerous in respect of wind pressure when putting out and hauling home the fishing nets? The lack of trim aft seemed a disadvantage, because it would not be easy to keep the ship and the fish holds dry.

Mr. A. C. Hardy said that Professor Jaeger, while calling his paper "A Note on Large Trawlers," was really inviting a discussion on fish factory ships. His own belief was that they were on the eve of the evolution of an entirely new ship type, the fish factory, the first real example of which would be on trial within the next few weeks. It was a question of whether such ships should be evolved from trawlers, which was rather Professor Jaeger's idea, or whether they should be new types. Mr. Hardy favoured the latter view. The first specially-built fish factory ship in the world, which was about to go on trials, was a completely new conception. It fished by a stern chute, had the machinery amidships and the working deck totally enclosed, and had a direct-coupled direct-reversing oil engine of the opposed-piston type. On the other hand, on the Pacific coast of America there were many ships of the fish factory type which were evolved from tank-landing ships. He had always held the view that the lessons of amphibious warfare had never been properly applied to peaceful pursuits and that those ships evolved during the war, landing ships (tanks), had much to recommend them for that purpose. On the Pacific coast, naval architects had made use of the double bottom, side walls and the splendid sea-keeping qualities of those vessels and used the deck, intended originally for armoured fighting vehicles, as a fish deck. He understood that the Russians had had ships built by Burmeister and Wain, at Copenhagen, which had deep freezing in their holds; they were about the same size as Professor Jaeger proposed. If the fish factory was to be a distinctive ship type in the future, would the ordinary trawler become obsolete? There were many who thought that the method of trawling on the quarter must disappear and that trawling through a stern chute would take its place.

There was a danger, in the case of the medium and small-size motor ships, of trying to make them like motor cars. The idea of having complicated gears, of making the main engines not only propel the ships, but do everything else at the same time, was wrong, and would be proved so by excessive maintenance bills and perhaps by complications with the gears. They must hold to simplicity in propulsion. He liked the idea of the reversible-blade propeller. It was possible to achieve a very good degree of control with it, and to adjust the pitch so as to give very nearly optimum conditions for running free and optimum conditions for trawling. Although there was, perhaps, a tendency for those on the bridge to fiddle with the gadgets in working the reversible blades, that was due probably to the sense of novelty. But the fishing ship of the future would have two crews, a cruising crew and a fishing crew; the captain would be expert in fishing and would still know how best to fix his propeller for the job he was doing.

Mr. E. R. Gueroult said that the big trawlers of about 200 ft. in length necessitated a difficult compromise in respect of the stability when the ship was light and when it was loaded. If, when light, there was a GM of something like 1 ft., there would not be too much stability when the ship was loaded. Regarding the big factory ships of the future, he felt that the design shown in the paper would probably be replaced by a larger ship, fishing over the stern by some method which would be closer to the American.

Captain J. P. Thomson, O.B.E., thought that Professor Jaeger, when he referred to a wind force of 6 to 7, rather under-estimated the weather conditions in which a trawler would work at sea. In a deep-water ship, the first indication of approaching land was often trawler, working on the 100-fathom line, with the men working under brilliant lights, sorting and gutting the fish. Looking at the illustration of the deep-freeze trawler, he was glad to note that shear had been retained. There was a tendency in big ships to build a parallel hull, adding a poop and a forecastle head, but the proposed ship retained her normal shear. He agreed with Mr. Hardy that everyting on board a trawler should be of the simplest design. It was not always possible to get the expert who could handle such high-class machinery. He did not agree, however, with the idea of having two crews; one crew must be the order of the day.

DESIGN CRITERIA

Professor E. V. Telfer thanked Professor Jaeger for giving so many references at the end of the paper, so that those who wished to acquaint themselves with what was known about trawler design could do so, as he intended to do. Referring to the figure showing the relation of $\frac{d}{B}$ and $\frac{L}{f}$ for motor trawlers, he asked how it was to be interpreted. There was a base of $\frac{d}{B}$

ratio. An increase in that ratio would presumably indicate deeper and less stable forms; yet the less stable forms were joined up in a curve with forms having the least freeboard on a given length. What did that mean? He suspected that the diagram was purely statistical and should not be used as a guide to good design; if it were so used, the effect might be to combine the worst stability with the least freeboard.

Professor G. C. Manning, in a written communication, said that those who taught ship design owed Professor Jaeger their thanks for the design information contained in his paper. The most important stability consideration for such craft as trawlers was the dynamical stability, measured by the area under the statical stability curve. Such vessels never got into trouble through a static heel; it was the force of wind and waves which caused their loss. As trawlers could not have a large freeboard, it was essential that they should have a substantial value for the metacentric height; otherwise, the curve of statical stability would have small height and small breadth and, therefore, inadequate area. For trawlers of the size discussed in the paper, it would seem reasonable to have the following minima in regard to stability, namely a metacentric height in all operating conditions of not less than 2 ft., a maximum righting arm of not less than 1 ft. at an angle of not less than 25 deg., and a range of stability of 60 deg.

Mr. W. F. Spanner, in a written contribution also expressed the opinion that generally speaking the value of the GM should be not less than 1 ft. for a condition approaching extreme light, with 10 per cent. of fluids and stores on board. Such a condition, while not commonly met with in practice, might be taken as an "arrival condition" in the unlikely, but possible, case of a trawler returning without fish. A larger value might be advantageous, giving some reserve. He thought that the calculation of the GM by Nickum's formula may well involve errors of appreciable magnitude, and that there was no substitute for a properly conducted inclining experiment when dealing with a matter so important as stability. Little mention was made of trimming and ballast tanks. It seemed advantageous to provide forward and after trimming tanks of reasonable size to enable the trim to be adjusted. Solid ballast of cement was not uncommon in such vessels, but water-ballast tanks had much to commend them, enabling the vessel to be kept at sea in an optimum condition of seaworthiness at all times.

AUTHOR'S REPLY

Professor Jaeger, in reply referring to Mr. de Rooij's statement that the variable-pitch propeller was 8 or 9 per cent. less efficient than the normal propeller, accepted it as a matter of experience. The optimum condition of the normal screw never arose in practice. On the question of higher towing speed, with the variable-pitch propeller the speed could be increased from 3½ to 3¾ knots and perhaps from 4¼ to 4½ knots, but probably never beyond 4½ knots. He knew nothing about the slime from fish reacting chemically with the light-alloy construction of fish holds, not having built a trawler with aluminium-alloy fish holds; but everybody was now building them in aluminium alloy throughout the world, so that he did not think the chemical reaction could be serious. Personally, he thought that aluminium alloys were the best materials to use where there were likely to be corrosive conditions, because aluminium protected itself. If necessary, however, the aluminium could be anodised. He knew of a case where Isoflex was glued directly to aluminium sheets, and would let Mr. de Rooij know the type of glue used. He would not advocate Diesel-electric propulsion for a ship such as the big deep-freeze trawler illustrated. Mr. de Rooij had said that it is not cheap; it was also very heavy and its application would have to be studied very carefully. The project had not advanced beyond the design stage, and was included merely to give an indication of what could be done.

He was interested to hear from Mr. Hardy of the fish factory ship which had been built and will soon be ready. He agreed with Mr. Gueroult that it was possible that the factory ships of the future might be bigger than he had proposed; and with Captain Thomson's view that the machinery should be as simple as possible. Replying to Professor Telfer, he had included the graph indicating the relation of $\frac{d}{B}$ and $\frac{L}{f}$ as a specimen. As he had stated in the paper, it might be used as a basis of approximation.

UNDERWATER TELEVISION

A vote of thanks to Professor Jaeger having been carried by acclamation, the chairman called upon Lieut-Commander J. N. Bathurst to present his paper on "Underwater Television." A summary of the paper is given below.

The first successful use of underwater television, said Lieut.-Commander Bathurst, was made by the United States in 1947, and the National Research Council of Canada also carried out several successful trials, but the first really practical test was in May, 1951, when it was used by H.M.S. Reclaim during the search for, and subsequent survey of, the submarine Affray. The set then used, developed at very short notice by the Royal Naval Scientific Service, proved very reliable and gave excellent results. In addition to their subsequent work, several civilian firms were making television equipment, notably Pye Limited, of Cambridge, and the Marconi Company, who had associated themselves in the work with the diving and safety-equipment firm of Siebe, Gorman, Limited. E.M.I. Limited, had also produced a camera for the Scottish Marine Biological Association. The most sensitive camera pick-up tube was the Image Orthicon, but less sensitive units were adequate for most underwater work. Television, like a diver, was wholly dependent on light, contrast, and water clarity for range of vision, but it could function at a lower light level than the human eye and had 10 to 15 per cent. greater range of vision than a diver in similar circumstances. There was under development a device known as the "clear water container" which could be fitted in front of the camera to increase its range artificially under conditions of bad visibility. At present, television could be used at depths down to 1,000 ft. and it was capable of development for use at greater depths if necessary, whereas the maximum practicable depth for a diver, even with special equipment, was 350 ft. Several viewing screens in the ship could be operated from the main set, and the picture could also be transmitted to the shore over a short distance. By filming or photographing the viewing screen, a permanent record could be obtained. It was the author's opinion that better underwater photography was to be obtained in that way than by the direct use of an underwater camera.

Lieut.-Commander Bathurst then gave an outline of the operations on H.M.S. Affray, illustrated with a number of slides made from photographs of the television screen in the Reclaim, and described how it was possible to direct the camera to obtain views that could not be obtained with an observation chamber, and to follow a diver's movements under water. The original apparatus was removed from the Reclaim after a year's use and a new set, made by Pye Limited, was fitted in its place. It had a motor-operated four-lens turret, enabling any one of the four lenses to be selected at will, and remote focus and iris control, so that the best quality of picture could be obtained in any given circumstances without having to raise the camera out of the water. The camera casing was of solid-drawn steel tubing, 22½ in. in diameter and ⅜ in. thick. The total weight of the camera was 17 cwt. and it could operate down to a depth of 1,000 ft. A lightweight camera had been developed also, weighing only 70 lb. in air and having a positive buoyancy in water of 1 lb., so that it could be handled by a diver or underwater swimmer; it could be used down to about 300 ft., which was sufficient for most underwater work in connection with surveys of underwater damage to ships, harbour installations, etc. It was small enough to be transported by air, together with its associated equipment and a portable generator. Because of the high initial cost, and the need to employ special operators, the author considered that the only practical way to exploit the possibilities of underwater television would be for the firms who made the equipment to have a number of sets, with operators, available for hire as and when they were wanted.

DISCUSSION

Lieut.-Comdr. Bathurst, in presenting the paper, added that his main object was to try to give the user's angle on television, because very little had been written to show what television will do and some of the immense possibilities it had for the future. He put the paper forward purely as a user. The use of television under water was still very much in its infancy. An immense amount of research was required, and he would say that the majority of the research and experience needed was in its application. In salvage operations it was often necessary for divers to survey wrecks or the bottoms of ships, and then to discuss matters and decide what repairs were necessary and the methods to be employed. Television, intelligently used, and if the conditions were right, should enable the technician, the surveyor or the naval architect to discuss the work directly with the diver, which should speed up operations immensely. Applied with a knowledge of its limitations, it should prove of inestimable value.

Air Chief Marshal Sir Frederick Bowhill said that, in investigating the accident to the Comet off Elba, underwater television had been used with the greatest success. Everybody concerned, connected with the air and the Royal Navy, had done marvellous work; they had recovered more than 60 per cent. of the Comet, which was a large proportion. Each piece was being examined very carefully, practically under the microscope. The evidence was negative so far, but that was not to say that they might not find something later on; even negative information was of the greatest use. Getting the four engines back was a magnificent job; they were all being stripped at Farnborough and examined carefully. So far, it appeared that the engines had nothing to do with the accident. He wanted to stress the part played by the Royal Navy, the Royal Air Force, and civil aviation, and to say how grateful they were to the inventors and improvers of that wonderful instrument, underwater television.

VALUE IN SHIP RESEARCH

Mr. L. G. Stevens said that part of his work consisted in damaging ships or targets by design, and sometimes even sinking them, and he felt that underwater television, when it had been developed somewhat farther, might be of considerable advantage in examining some of the results. On a recent occasion, they wanted to see what had happened to a target after successive explosions. They were faced with the question whether to raise the target after each explosion, with the possibility of damaging it more in the operation of lifting, whether to infer what had happened, or whether to rely on a diver, who might not be able to tell them exactly what they wanted to know. In such a case, television would be extremely useful. Looking perhaps farther into the future, to be able to see what was going on under water might sometimes be more valuable to the research worker than the making of accurate measurements, by indicating the directions in which to look for the explanation of results. In the model field, developments in

photography had been of the highest value; if, on the full scale, it was possible to observe what was happening with anything like the same facility, it would be extremely valuable, for example, in solving some of the problems of scaling which were so elusive. It was not clear what advantage underwater television, used in association with cinephotography, had over the direct use of a submerged cinecamera; it would seem that direct cinephotography would be likely to give better pictures than relaying them to the surface by underwater television and making the film there. Underwater phenomena were, unfortunately, transient, of very short duration, and in that connection underwater television might help; where there are recurrent phenomena, such as were associated with the propeller, or possibly even underwater vibration, if high frame rates could be used with television and something in the nature of stroboscopic observation, it might be possible to see what was going on. The problems of illumination, however, and also of the set-up, which would have to vary from operation to operation, would be formidable.

Professor E. V. Telfer suggested that, if a television camera could be made part of the ordinary equipment of the tank truck travelling along the tank, so that any of the phenomena could be probed at will, they should be able to see what was happening not only on the truck, but on other screens in various offices, thus enabling a number of people to examine the same things at the same time. If that was done, there was probably a field for the cinecamera also, but the first exploration, he thought, would be better done by television. The United States had been developing a circulating water tunnel, costing over a million dollars; it was an expensive piece of equipment to run, because huge power was required to circulate the water. A television camera might do what it had been thought could best be done in the circulating water tunnel.

LIGHTING DIFFICULTIES

Mr. G. MacNiece, of the Admiralty Research Laboratory, said that the paper was the first that had been presented on the application of underwater television. After all, that was the important side; they could not decide what sort of underwater television camera to concentrate on without knowing what the application was to be. Underwater television had been applied to oceanography and to marine biology. The Scottish Marine Biological Association had been using a camera for about two years to study the habits of fish. In addition, they had carried out an expedition in which the oceanographers and biologists were enabled to study the sea floor at depths down to 4,000 ft. He thought that the application to locks and docks must be treated with some care because, with few exceptions, in locks and docks the water was extremely dirty. It was disappointing when people wanted to examine a lock or a dock, to have to tell them that the television method probably could not be used there. That happened in the case of the Empress of Canada, at Liverpool; they were asked if they could help, but after one quick look at the water in the dock television was ruled out. In the future, it might be possible by using the clear-water viewers and by other means, but those viewers were rather difficult things to use, and it was not a nice application.

On the technical side there was one point that he might clear up, concerning the camera pick-up tube. It was very complex and, in a way, difficult to use, but it gave high-contrast sensitivity. That was very important under water, because invariably there was the equivalent of a mist or fog in water, which reduced the contrasts of the objects viewed; so that the tube, which emphasised the contrasts, was of great value. The slightly greater range of television, he would suggest, was an academic point, and he did not think that, in practice, it could be put forward as an argument in favour of television. They regarded television purely as an adjunct to the diver or salvage expert, and did not try to push it forward for use where other and simpler means could be applied.

Captain G. C. Saul asked the author for some information about the clear-water container, as it was a device about which, he thought, not much was generally known.

Captain J. P. Thomson, O.B.E., thought that there was a great future for underwater television, in connection with the ordinary occurrences at sea which, unfortunately, the sailor had to deal with from time to time; for example, underwater inspections, for the examination of the rudder and propeller, and of bottom damage. There had been times when he would have given much to know what damage had been done to the bottom of the ship. It was unfortunate that television was not so good in muddy water; but in many ports the water was not muddy, and, in many cases, television could be used outside the ports.

Sir Stanley V. Goodall recalled that his predecessor as Director of Naval Construction once said that, every time a submarine disaster occurred, he was not able to sleep for several nights. That indicated the burden which rests upon the naval architect, and the trouble that might come to him when something had gone wrong with a ship for the design of which he was responsible. He himself had been responsible for the design of the " A " class of submarines, and he had passed that burden on to Sir Charles Lillicrap when the disaster to the Affray occurred. While it was true that the examination made by the television apparatus, to a certain extent, had given negative results so far in the case of the Comet disaster, it did set his mind at rest that some of the wild rumours circulated after that disaster were based entirely on conjecture and not on fact.

Mr. W. J. Ferguson, speaking on behalf of the Institute of Marine Engineers, thanked the author for having drawn attention to such an extremely useful tool. Its application would be of the greatest interest to the shipowner, the underwriter, the repairer, and the surveyor responsible for the recommendations before a ship went to sea, in cases where ships suffered damage. Whether to use an underwater television camera or the normal procedure would depend on the availability and the cost of the television camera, and he asked whether, in the near future, the apparatus and trained people were likely to be available at reasonable cost in any part of the world. He could imagine that the time would come when television cameras would be used extensively; but a certain amount of propaganda would be necessary if it was to be used to advantage.

Dr. S. F. Dorey asked whether the infra-red ray had been used for illumination where the camera operated at depth in somewhat cloudy water.

CLEAR-WATER CONTAINERS

Lieut.-Commander Bathurst, in reply, said that, with regard to the use of the infra-red ray, he thought that the scattering and diffusion was such that there was not sufficient light penetration under water. As to availability and cost, television equipment was very costly and it needed experts to maintain it, but developments are being made all the time in underwater television equipment. Because it was costly, it did not seem a particularly good thing for a docks and harbour board to invest in a set. It seemed that the ideal arrangement would be for the manufacturers to build the equipment and to have it available at various ports in the world, or available for rapid transit to ports by air. With it would go the necessary technician to operate it. Thus the user would get the latest equipment which the manufacturers had in their factories. Exactly how far the various manufacturers would be prepared to go in having equipment and engineers scattered all around the world was purely a commercial matter.

The clear-water container was a pack made with transparent plates and filled with fresh water. It was attached to the front of the camera and provided a cone of fresh water between the camera and the object. Whereas without it the illumination might give a range of only 3 ft., by using a clear water container it might be possible to see to a distance of 9 ft. He was not in a position to answer the question concerning the use of a camera on the tank truck. There were very small cameras available. For such an application, working in clear water, there was a camera measuring about 10 in. by 5 in. by 5 in. That might involve using one of the camera pick-up tubes. In spite of what Mr. MacNiece had said, wherever television was used under water under similar conditions to divers' observation chambers, he was convinced that it was possible to see farther with television. The television screen could be artificially brightened, and the light losses on the emulsion of the cine film offset to a certain extent thereby. Perhaps Mr. MacNiece could explain that more fully.

Mr. MacNiece responded that, in regard to the remarks about filming the screen, he thought that the author had in mind that, when using a television camera for inspection and something interesting appeared, worthy of record, the screen would be photographed. He did not think it was intended to suggest that, to make a cine film of an object under water, it was advisable to employ all the paraphernalia of television camera, screen, etc. There was, however, another point, namely, that the television picture could be obtained at a much lower light level than would be required for satisfactory cinephotography; in other words, if the television camera was down, in conditions of poor illumination, whether daylight or artificial light, and the screen brightness could be increased to a point at which it could be photographed adequately with the cine camera.

On the conclusion of the discussion, a film was shown of the televising of a wreck which was sunk by torpedo in the 1914-18 war.

To be continued

* * *

SHORTAGE OF SCIENCE TEACHERS

Appointment of Committee

The serious effect on industry of the shortage of science teachers in schools was the subject of a conference of educationalists and industrialists organised by the Federation of British Industries 21 Tothill-street, London, S.W.1, in January. A resolution passed at the conference recommended the Federation to set up a committee, representative of education, industry, and other employers of scientists, with the aim not only of improving the supply of science teachers to the schools in the difficult years from 1955 to 1960, but of seeking a permanent solution.

Following this recommendation, the Federation has formed the " Committee on the Shortage of Science Teachers," with Dr. Percy Dunsheath, C.B.E. (chairman of the Federation's education committee) as chairman, and the following members:

Representing schools are: Miss M. J. Bishop, C.B.E., Mr. W. R. Hecker, Mr. Ian Hepburn, Dr. W. G. Humphrey and Miss K. E. Parks.

Representing universities are: Professor J. W. Cook, F.R.S., Glasgow, Mr. J. G. W. Davies, O.B.E., Cambridge, and Professor E. Giffen, London.

Representing technical colleges is: Dr. G. E. Watts, principal, Brighton Technical College.

Representing industry are: Mr. A. D. Bonham-Carter, Unilever, Ltd.; Dr. W. S. Bristowe, Imperial Chemical Industries Ltd.; Mr. G. S. C. Lucas, C.B.E., British Thomson-Houston Co. Ltd.; Mr. J. A. Oriel, C.B.E., Shell Petroleum Co. Ltd.; Mr. L. A. Pilkington, Pilkington Bros. Ltd.; Mr. M. Seligman, The A.P.V. Co. Ltd.; and Mr. A. H. Wilson, F.R.S., Courtaulds Ltd.

Representing Government and nationalised industry are: Dr. B. K. Blount, Department of Scientific and Industrial Research; Sir George Gater, G.C.M.G., K.C.B., Ministry of Labour; and Mr. M. Milne-Watson, North Thames Gas Board.

THE OUTPUT OF GYRATORY CRUSHERS

By K. Gauldie, B.SC., M.C.I.M.M.

The gyratory crusher may be regarded as a jaw crusher in which a large number of elementary, V-shaped jaws operate in succession. Each of these elementary jaws is advanced and retracted in each revolution and each contributes its share to the total output of the machine. If all these jaws were to operate simultaneously the output rate of the machine would be the same as if they operated in sequence. As far as output is concerned the moving crushing surface may be regarded, therefore, as expanding and contracting, umbrella fashion, in simple harmonic manner. In the following discussion the movement of material between the crushing surfaces is considered and described as if the moving surface, instead of gyrating about an eccentric axis, breathed backwards and forwards from a fixed axis. According to this picture crushing occurs during the "expansion stroke"; and during the "contraction stroke" descent of material takes place.

The problem of output calculation is, then, essentially the same in the gyratory as in the jaw crusher. [See article on "The Performance of Jaw Crushers," ENGINEERING, vol. 176, pages 456 and 485 (1953).] For values of the angular functions, Q and R, used in the present article, see Table I and the corresponding curve, Fig. 6, of that article. A main difference is that in the gyratory machine the prisms of broken material which descend per stroke past all levels are not, as a rule, of constant horizontal length as in the jaw crusher, but are rings, the length of which ordinarily increases, as descent progresses. A further difference is that, in gyratory machines, the downward movement of material takes place, as a rule, along an inclined surface. Angle of inclination and friction are, therefore, factors on which, in general, the output rate of gyratory crushers depends.

The mass of material in a ring of sectional area, a, is $2\pi r a \delta$ where r is the radius of the centre of gravity of the area and δ is the mean density of the material of the ring. In a crusher running at constant speed and discharging at uniform rate, the same mass of material is contained in the rings which descend per stroke past all levels. The basic output equation of the gyratory crusher is, therefore:—

$$a r \delta = \text{constant}. \quad . \quad . \quad (1)$$

The nature of the occurrences in the crushing zone of a gyratory crusher is indicated in Fig. 1 herewith. A stream of feed material, the larger lumps of which are assumed to be all of the same known thickness, slides intermittently down the upper part of the oscillating cone. At the moment when the cone is in the "fully expanded" position, no downward movement is occurring and the larger lumps on the upstream side of the stream face at the nip level, F, are in loose contact with both crushing surfaces. As the cone "contracts," the stream moves downward and outward; and if the cone is oscillating at less than the local critical speed at the level, F, the stream face descends past that level through the distance, h_f, during the contraction stroke of the cone, and is again arrested at the end of that stroke. The sectional area of the ring which has descended past nip level during the contraction stroke of the cone is the shaded rectangular area, of which the length is h_f and of which the breadth, b_f is equal to the thickness of the larger lumps in the stream. The sectional area of the rectangular ring which descends per stroke past nip level in a machine operating at, or at less than, the local critical speed at that level is, therefore, $h_f b_f$.

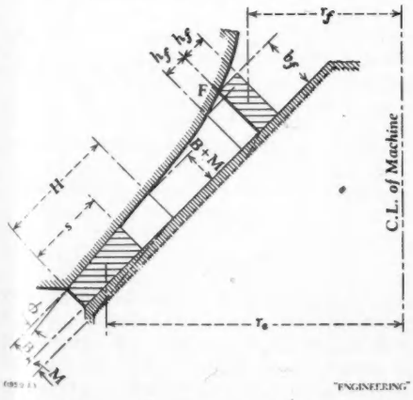


Fig. 1 The crushing zone of a gyratory crusher.

At higher speeds the time available for descent past nip level is insufficient for movement through the full distance, h_f; and the material slides down the cone through some lesser distance s_f. In general, then, the sectional area of the rectangular ring which descends per stroke past nip level is:—

$$a_f = s_f b_f, \quad . \quad . \quad . \quad (2)$$

where s_f is less than or equal to h_f, according as the speed of the machine exceeds or does not exceed the local critical speed at nip level.

At the outlet, the ring of material which emerges per stroke is of wedge section. At speeds up to the critical the emergent material moves the full distance, H, during the contraction stroke of the cone. At higher speeds, the emergent rings are of lesser length, s, and lesser area. In general, as in the case of the jaw crusher, the sectional area of an emergent ring is

$$a_e = s\left(\mathrm{B} + \frac{\mathrm{M}\,s}{2\,\mathrm{H}}\right). \quad . \quad (3)$$

where s is less than, or equal to H according as the speed of the machine exceeds or does not exceed its critical speed.

In a machine running at constant speed and discharging at uniform rate, the same mass of material, $2\pi ra\delta$, descends per stroke past all levels in the crushing zone. In terms of the conditions at nip and outlet levels, the output rate of the machine is, therefore :

$$w = 2\,\pi\,n\,a_f\,r_f\,\delta_f = 2\,\pi\,n\,a_e\,r_e\,\Delta, \quad (4)$$

where n is the frequency of oscillation of the cone, a_f and a_e are the sectional areas of the rings which descend per stroke past the nip and outlet levels, r_f and r_e are the radii of the centres of gravity of these areas, and δ_f and Δ are the mean densities of the material in the rings.

These areas and radii depend on the lengths, s_f and s, of the respective rings, and, if these lengths are known, may be calculated or measured from a layout. The problem of calculation of the output rate of a crusher operating at a given speed is, therefore, primarily the problem of calculating these ring lengths.

In terms of the units of measurement usually employed, equation (4) takes the forms :

$$\mathrm{T} = \frac{\mathrm{N}\,a_e\,r_e\,\Delta}{\mathrm{C}}, \quad . \quad . \quad (5a)$$

or

$$\mathrm{T} = \frac{\mathrm{N}\,a_f\,r_f\,\delta_f}{\mathrm{C}}, \quad . \quad (5b)$$

where T is the output rate in tons per hour, N is the speed in revolutions per minute, mean densities are reckoned in pounds per cubic foot, areas and radii are measured in inches, and where the constant C is 10,300 for tons of 2,240 lb. and is 9,200 for tons of 2,000 lb.

The latter equation serves to emphasise the fact that output rate depends primarily on conditions at nip level and is applicable if the mean density, δ_f, of the material as it arrives at nip level is known. The condition that the mean density of the emergent material cannot exceed the practical limit must, however, always be satisfied. For that reason the former equation is the more appropriate for general use.

In a crusher running at less than critical speed, an emergent wedge is in contact with both crushing surfaces during at least the latter part of its downward step and completes that movement under the restraint of both surfaces. In a crusher running at critical, or greater speed the material, if non-sticky and non-caking, loses contact with the fixed crushing surface immediately the cone commences to move backwards in a "contraction" stroke, remains out of contact with that surface during the whole of its downward movement, and descends under the sole restraint of the surface of the moving cone.

The acceleration, in the direction of movement, under which material slides down a fixed surface is (Fig. 2) :

$$i = g\,(\sin\psi - \mu\cos\psi), \quad . \quad (6)$$

where ψ is the angle of inclination and μ is the coefficient of friction between the material and the surface.

In a crusher, the surface down which the material slides is not, however, at rest. It oscillates through a small angle and its inclination varies to a slight extent above and below the mean.

Moreover, the surface is being accelerated, sometimes away from and sometimes towards the material in contact with it. The pressure of the material on the surface and the frictional resistance to its downward movement vary, therefore, above and below their mean values. As these deviations from mean conditions more or less compensate for each other, it may be assumed, without serious error being involved, that the mean acceleration under which the material slides down the oscillating cone is the same as if the cone were at rest, and that, where ψ is the mean angle of inclination (the base angle of the cone) equation (6) applies.

For convenience that equation may be written:—

$$i = jg,$$

where $\quad j = \sin\psi - \mu\cos\psi. \quad . \quad (7)$

If out of contact with the fixed crushing surface during the whole of its downward movement, an emergent wedge, starting from rest at the beginning of a contraction stroke, would slide down the surface of the cone through the distance s, in the duration, t, of that stroke, where:—

$$s = \frac{i\,t^2}{2} = \frac{i}{2}\left(\frac{1}{2\,n}\right)^2 = \frac{jg}{8\,n^2}.$$

When the machine is running at the critical speed, n_c, the distance, s, is the same as the distance, H, whence:—

$$\mathrm{H} = \frac{jg}{8\,n_c^2}.$$

The critical speed of the machine is, therefore:—

$$n_c = \sqrt{\frac{jg}{8\,\mathrm{H}}}; \quad . \quad . \quad (8a)$$

or, in terms of revolutions per minute,

$$N_e = 60\sqrt{\frac{jg}{8H}}; \quad . \quad . \quad (8b)$$

or, when H is measured in inches,

$$N_e = \frac{417\sqrt{j}}{\sqrt{H}}. \quad . \quad . \quad (9)$$

As the speed is increased beyond the critical, the length, s, of the emergent wedges decreases and (as in the case of the jaw crusher) is:—

$$s = \frac{H(1+\cos\alpha)}{2} = HQ, \quad (10)$$

where α is the angle through which the eccentric has moved past its backward dead centre at the instant when, at outlet, the material immediately above the upper end of the emergent wedge has been arrested, between the fixed crushing surface and the base of the advancing cone.

This downward and outward movement, s, has occurred (as in the jaw crusher) while the eccentric moved through the angle, $\pi + \alpha$, and has taken place in the time, t, where:—

$$t = \frac{\pi+\alpha}{2\pi} \times \frac{1}{n}.$$

Whence

$$s = \frac{jt^2}{2} = \frac{jg(\pi+\alpha)^2}{8\pi^2 n^2}.$$

It follows, therefore, that

$$\frac{jg(\pi+\alpha)^2}{8\pi^2 n^2} = \frac{H(1+\cos\alpha)}{2};$$

and consequently that

$$n = \frac{\pi+\alpha}{2\pi}\sqrt{\frac{jg}{H(1+\cos\alpha)}},$$

or in terms of revolutions per minute, that

$$N = \frac{60(\pi+\alpha)}{2\pi}\sqrt{\frac{jg}{H(1+\cos\alpha)}}.$$

When the angle, α, is measured in degrees and the length, H, in inches, the above equation takes the form:—

$$N = \frac{3{\cdot}27(180+\alpha)}{\sqrt{1+\cos\alpha}}\sqrt{\frac{j}{H}} = R\sqrt{\frac{j}{H}},$$

or:—

$$R = N\sqrt{\frac{H}{j}}. \quad . \quad . \quad (11)$$

Similarly, the local critical speed at nip level is:—

$$N_f = \frac{417\sqrt{j}}{\sqrt{h_f}}, \quad . \quad . \quad (12)$$

the distance through which, at that and higher speeds, material descends per stroke past nip level is:—

$$s_f = \frac{h_f(1+\cos\alpha)}{2} = h_f Q, \quad . \quad (13)$$

and for speeds equal to and greater than the local critical speed at nip level

$$R = N\sqrt{\frac{h_f}{j}}. \quad . \quad . \quad (14)$$

For any particular values of H, j and N, the value of the angular function, R, follows from equation (11). The value of the corresponding function, Q, may then be obtained from the QR curve, which is the same for gyratory as for jaw crushers; whence, by equation (10), the length, s, of the wedges which emerge per stroke from a machine running at the supercritical speed, N, may be arrived at. In similar manner, by applying equations (14) and (13), the length, s_f, of the prisms of material which descend per stroke past nip level may be calculated. At speeds up to the critical, the length, s, is, of course,

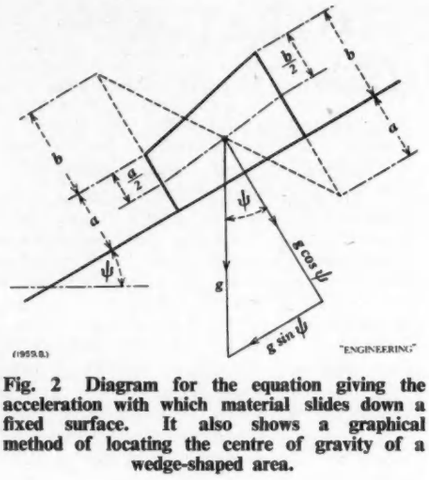


Fig. 2 Diagram for the equation giving the acceleration with which material slides down a fixed surface. It also shows a graphical method of locating the centre of gravity of a wedge-shaped area.

equal to the length, H; and at speeds up to the local critical speed at nip level, the length s_f is equal to h_f.

The lengths, s and s_f, having been established, the corresponding values of the areas, a_e and a_f, follow from equations (3) and (2); and the radii, r_e and r_f, of the centres of gravity of these areas may be measured from a layout. A graphical method of locating the centre of gravity of a wedge-shaped area is indicated in Fig. 2.

It is implied in the equations that the emergent wedges are straight-sided; that is, it is implied, that the fixed crushing surface is straight in radial section for a distance from the outlet at least equal to the calculated length, s, of the emergent wedges; and the equations apply only if this condition is satisfied. At a greater distance from the outlet, the fixed crushing surface may curve towards the receiving opening. For that reason, the distance H should not be measured directly from the layout, but should be reckoned as M cot ϕ, where M is the stroke of the cone and ϕ is the angle included between the crushing surfaces when at their closest approach, both at the outlet.

In a particular example to illustrate the procedure of calculation, the outlet diameter of the fixed crushing surface of a secondary crusher is 36 in.; the close setting, B, is 1 in.; the cone movement, M, at outlet is $\frac{7}{8}$ in.; the angle, ϕ, included between the crushing surfaces at outlet is 2 deg.; the corresponding length, H, reckoned as M cot ϕ is 25 in.; and the base angle, ψ of the cone is 56 deg. The one-way size, b_f, of the feed material is 4 in., and the length, h_f, at the 4-in. nip level, as measured from a layout, is 1·41 in. The mean density of the feed material as it would arrive at nip level in a choke-fed machine is 75 lb. per cubic foot; and the maximum mean density to which the emergent material may be compacted is 120 lb. per cubic foot. The coefficient of friction, μ, between the cone surface and the descending material is 0·3, and the operating speed, N, of the machine is 300 r.p.m.

In this particular case, the acceleration factor, j, in equation (7) is sin 56 deg. − 0·3 cos 56 deg. and amounts to 0·66. The local critical speed at the 4-in. nip level is, therefore:

$$N_f = \frac{417\sqrt{\cdot 66}}{\sqrt{1{\cdot}41}} = 286 \text{ r.p.m.}$$

and is less than the operating speed. The distance of descent, s_f, at nip level is, therefore, less than h_f, that is, it is less than 1·41 in. and must be arrived at by calculation.

For the conditions at nip level, the value of the angular function R, is, by equation (14),

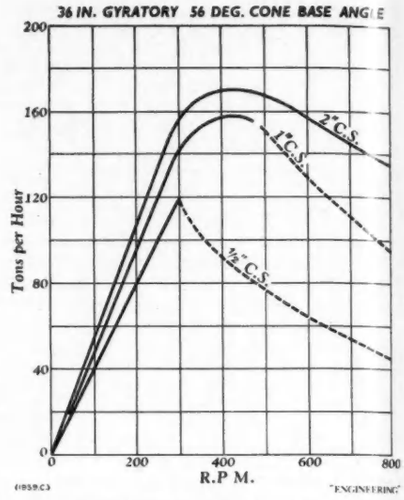


Fig. 3 Output-speed curves for close settings of $\frac{1}{2}$ in., 1 in. and 2 in.

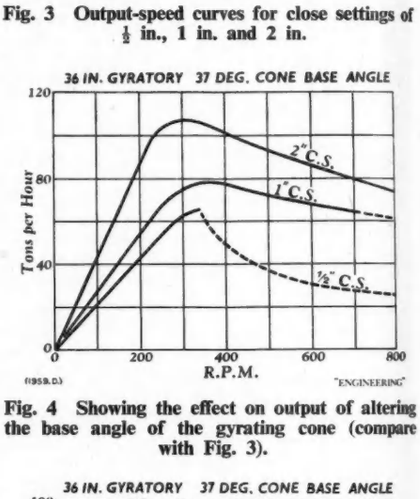


Fig. 4 Showing the effect on output of altering the base angle of the gyrating cone (compare with Fig. 3).

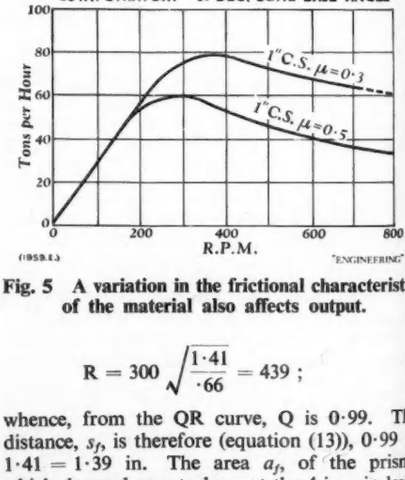


Fig. 5 A variation in the frictional characteristic of the material also affects output.

$$R = 300\sqrt{\frac{1{\cdot}41}{\cdot 66}} = 439;$$

whence, from the QR curve, Q is 0·99. The distance, s_f, is therefore (equation (13)), 0·99 × 1·41 = 1·39 in. The area a_f, of the prisms which descend per stroke past the 4-in. nip level (equation (2)) is 1·39 × 4 = 5·55 sq. in.; and the radius, r_f, of the centre of gravity of this area, as measured from a layout, is 11·6 in.

Similarly, for conditions at the outlet (equation (11))

$$R = 300\sqrt{\frac{25}{0{\cdot}66}} = 1{,}850,$$

and the corresponding value of Q is 0·15. The distance of descent, s, at the outlet is, therefore, 0·15 × 25 = 3·75 in.; whence, by equation (3), the area, a_e, is 4·0 sq. in. By measurement from the layout, the radius, r_e, of the centre of gravity of this area is 16·5 in.

The mean density of the emergent material, by equation (1), is:—

$$\Delta = \frac{a_f r_f \delta_f}{a_e r_e} = \frac{5{\cdot}55 \times 11{\cdot}6}{4 \times 16{\cdot}5} \delta_f = 0{\cdot}975\, \delta_f.$$

The mean density, δ_f, of the material as it arrives at the nip level cannot, by assumption, exceed 75 lb. per cub. ft. The mean density, Δ, of the emergent material cannot, therefore, be greater than 73 lb. per cub. ft.; and as that density is within the practical limit (120 lb. per cub. ft.) the machine operating at 300 r.p.m. could be choke fed. The output rate of the choke-fed machine is, therefore, by equation (5*a*):—

$$T = \frac{300 \times 4 \times 16{\cdot}5 \times 73}{10{,}300} = 140 \text{ tons per hour.}$$

With regard to the quality of the discharged material, the greatest one-way thickness, E, of the emergent fragments is equal to the thickness of the upper ends of the mergent wedges and is:—

$$E = B + \frac{M\, s}{H} = 1 + \frac{\frac{7}{8} \times 3{\cdot}75}{25} = 1{\cdot}13 \text{ in.}$$

The one-way size of the larger fragments would vary, therefore, from 1 in. to roughly 1⅛ in.; so that unidirectional degree of uniformity of the product would be reasonably high.

The higher the operating speed, the less is the length, *s*, of the emergent wedges and the more uniform in one-way size is the discharged material; in this particular case, the quality and, up to a point (see Fig. 3) the quantity, of the product would be improved by operation at higher speed.

Fig. 3 comprises the output-speed curve for 1-in. close setting, calculated (except as regards speed) for the same conditions as in the previous example, together with similarly calculated curves for ½ in. and 2 in. close settings. To illustrate the effect of cone angularity on output rate, the corresponding curves in Fig. 4 were drawn. The conditions are the same in both cases, except that the base angle of the gyrating cone is 56 deg. in the former and is 37 deg. in the latter case. Fig. 5 illustrates how greatly the output rate of a crusher may be affected by the frictional resistance of the cone to the downward movement of material along it (that is, by the nature of the material) particularly if the base angle of the cone is low.

In all these curves the speed ranges over which feed restriction would be necessary to maintain the mean density of the emergent material within the practical limit are indicated in dotted lines; and the ranges over which choke feeding would be practicable are drawn in full lines.

An output rate calculated, as in the example taken, from end conditions only, would be attainable if, at a lower output rate, the mean density of the fragmented material at an intermediate level did not reach the practical limit. Should that condition not be satisfied, feed restriction would be necessary to prevent over-compacting at the intermediate level; and the output rate would be limited accordingly. As the mean density of the material at intermediate levels depends on, among other circumstances, the shape of the fixed crushing surface between the nip and outlet levels, the output rate may depend on that shape.

If the volume of the descending wedges is less, at outlet than elsewhere, that is, if the product, $a\,r$, is less at the outlet than at any higher level, the mean density of the fragmented material is greatest at the outlet; and the output is not restricted by conditions at intermediate level. The condition for greatest output with minimum risk of over-compacting is, therefore, that the product, $a_e r_e$, should not exceed the corresponding product, $a\,r$, at any higher level.

The shape of the fixed crushing surface to comply with this condition can be arrived at by trial and error methods on the lines described for jaw crushers, the only difference being that, in the case of the gyratory crusher, the radius, *r*, of the centre of gravity of the descending rings must be taken into account.

It is naturally at the lowest setting that the risk of over-compacting and the likelihood of the output rate being limited by conditions at intermediate level, are greatest. For that reason, it is at the lowest setting at which a machine is designed to operate, that the condition that the product, $a\,r$, is least at outlet should, if practicable, be satisfied.

* * *

VERMICULITE

Modern Uses of an Expansible Mineral

The earliest date for the use of the word "vermicular" given by the Oxford Dictionary is 1672. It is derived from the Latin *vermis*, a worm, and means "having the sinuous shape or form characteristic of a worm." When, in 1824, Thomas H. Webb found a mineral in a talc deposit near Worcester, Mass., in the United States, which, in his words, "if subjected to the flame of a blowpipe . . . expands and shoots out into a variety of fanciful forms, resembling most generally small worms having the vermicular motion exact." On the basis of this behaviour, he termed the mineral "vermiculite."

Although Webb's observation was made in 1824, it was not until 1913 that, in Colorado, the first large deposit of the material was found, and not until 1915 that it was marketed commercially in the exfoliated form, that is, after heat treatment. The mineral has now been found in twelve of the States of the United States and is in commercial exploitation in seven. In 1951, 209,008 short tons of screened and cleaned vermiculite were sold or used, by producers in the United States, and 200,000 short tons of exfoliated vermiculite were sold or used. The mineral has also been found in the Union of South Africa, Tanganyika, Kenya, Uganda, Rhodesia, Canada, India, Australia, Mexico, Chile, Brazil, Japan and Russia.

Vermiculite is a hydrated magnesium-aluminium silicate, but different deposits vary considerably in composition. The specific gravity of the mined material is about 2·5 and the fusion point 2,462 deg. F. When heated, with exfoliation, it gives off considerable quantities of water and increases in bulk by some 8 to 12 times. The crude mineral is comparatively soft and winning presents little difficulty. It is crushed and screened and subjected to a temperature of about 500 deg. F. to drive off entrained water, and it is important to keep the temperature low enough not to drive off combined water. Exfoliation is carried out in oil-fired vertical-shaft furnaces at temperatures of from 1,600 deg. to 2,000 deg. F. The charge, fed into the top of the furnace, passes over a series of staggered baffles in its fall through the heated zone and is received by a bucket elevator which carries it to a cyclone in which unexpanded rock particles are removed and the material is cooled. The entire operation, from feeding the furnace to bagging the product, is stated to take only a few minutes.

THERMAL AND ACOUSTIC INSULATION

It is in virtue of its low bulk density, comparatively high refractoriness, low thermal conductivity and chemical inertness that vermiculite is of value for thermal and acoustic insulation and for the production of lightweight concrete and plasters. It suffers from the defects of its qualities and is so bulky that it is impracticable to ship it for long distances; the exfoliation process has to be carried out in the neighbourhood of the consuming market. One of the common uses is as loose fill in hollow walls, between joists in attics and as thermal insulation for roofs, ceilings and walls. It is also used in the form of plaster as a fireproof casing over joists and columns. In a form known as acoustic plaster, in which the exfoliated vermiculite is reinforced with fibrous material and a binder, it is applied to house and office walls to deaden sound transmission.

LIGHTWEIGHT CONCRETE

One of the major applications of the material is as an aggregate in lightweight concrete. This is made in a wide variety of qualities and of weights ranging from 16 to 50 lb. per cubic foot, the compressive strength varying from 50 to 500 lb. per square inch. It is mainly used as an insulating material for roofs and floors, but reinforced by a backing of thin steel or aluminium sheet, has been employed for walls in multi-storey buildings. It has also been used, in the form of slabs, for the roofs of both temporary and permanent buildings.

A detailed description of the nature and many uses of vermiculite is given in Information Circular 7668, of the Bureau of Mines of the United States Department of the Interior, and this article is based on that Circular. The information given is naturally concerned, in the main, with the production and employment of vermiculite in the United States. It is, however, stated that, outside that country, only the Russian and South African deposits are known to have been worked on a commercial scale. Little information appears to be available about operations in these countries. Large quantities of the mineral are exported from the Transvaal deposits to Great Britain, the United States and Canada; a Canadian company which formerly processed South African vermiculite is now working a deposit in Ontario. It does not appear from this Circular that the deposits in the British African Colonies are being exploited.

* * *

COMMEMORATING THE LATE DR. H. W. DICKINSON

Newcomen Society Memorial Lecture

Dr. Henry Winram Dickinson, M.I.Mech.E., who died in 1952 and was President of the Newcomen Society for the Study of the History of Engineering and Technology from 1932 to 1934, is to be commemorated by a lectureship which the Society has established in collaboration with its affiliated organisation in North America. Dr. Dickinson was a founder member of the Newcomen Society and served as its honorary secretary for more than 30 years. As a writer on engineering history, he attained widespread renown.

Dickinson Memorial Lectures will be delivered at intervals of two years, commencing in 1954, and it is intended that the lecturers shall deal with topics connected with technological and scientific history in a manner likely to appeal to audiences which are, to some extent, non-technical. Each lecturer will be presented with a commemorative bronze medal.

The first lecture will be delivered by Professor Charles Singer, M.D., D.Litt., on "The New Era in the History of Technology," on Wednesday, May 12, at the Science Museum, Exhibition-road, South Kensington, London, S.W.7, commencing at 6 p.m. Dr. Dickinson was keeper of the museum's mechanical-engineering collections for many years, prior to his retirement in 1930.

IMPEDANCE NETWORK ANALYSER

THE STUDY OF POWER SYSTEM AND OTHER PROBLEMS

A network analyser which has recently been installed at the works of A. Reyrolle and Company, Limited, Hebburn, Co. Durham, is of the impedance type, as distinct from the analogue type, and will be used mainly for studying power-system problems, such as voltage regulation, load distribution, and synchronous stability, as well as the rates of rise of re-striking voltage and physical and mechanical problems of a similar character. A view of the equipment is given in Fig. 1. The design follows orthodox lines, except that a frequency of 1,592 cycles is employed, instead of the more usual 500 cycles.

BASIC PRINCIPLES

In principle the analyser consists of 276 variable-impedance units for simulating the elements of a power system. These units, 12 of which represent generators, 120 the line, 36 loads, 36 auto-transformers and 72 capacitors, can be linked by plug and socket connections to represent an equivalent electrical circuit. Of the 36 load units 16 have built-in auto-transformers and each load unit has a load voltmeter associated with it. With the exception of those representing generators, these units are arranged in four groups, each group being associated with a marshalling cubicle or plug board at which the appropriate interconnections can be made. The 12 generator units can be connected to any of the four marshalling cubicles and inserted into the system. All the main metering is done from the control desk visible in the foreground of Fig. 1 in the centre of which are four master instruments – an ammeter, a voltmeter, a wattmeter and a varmeter. These instruments, which are of the air-cored dynamometer type with light-spot indication, can be connected to any part of a system which is being studied by a selector system. A fifth master instrument is a phase-angle indicator which is mounted on the right-hand front of the desk. It consists of a cathode-ray tube with a scale marked in degrees on its screen. Indication is by "pips" on a circle, thus showing the phase relationship between the voltage and current of any unit that is being metered with respect to each other or to some arbitrary reference.

The main source of power supply to the analyser is a valve-maintained tuning-fork which produces an accurately-controlled voltage at 1,592 cycles per second. This is a single-phase source and is fed into a phase-splitting device to give a two-phase supply. This two-phase power is supplied to 12 continuously-variable phase-shift devices, the single-phase outputs of which are fed into continuously-variable voltage-transformers. At the terminals of these voltage-transformers there are therefore 12 sources of supply of variable phase and variable magnitude. These 12 sources are fed into 12 output-amplifiers with very low output impedances and thence into the generator-impedance units. The output-amplifiers and their associated impedance units are mounted in the centre of the analyser. The connections from the 12 generator-impedance units are taken through selector switches to one or other of the marshalling cubicles. Each generator unit has its own monitoring wattmeter, voltmeter, and varmeter.

LINE AND CAPACITOR UNITS

The other units are line units consisting of an adjustable inductance and series resistance; capacitor units, which can be either series or shunt connected, and can represent line or cable capacitance, synchronous condensers, or bulk capacitors; load units which consist of resistance and inductance for shunt connection; and auto-transformer units which are used to simulate tap-changing operations. Fig. 2 shows a typical line-unit with the decade switches for inductance and resistance adjustment.

Fig. 3 is an illustration of a marshalling and plug board set up for a study. As will be seen the various units terminate in flexible leads and three-pin plugs at a plug-board, and the plugs can be inserted into sockets. In order to interconnect two units their plugs are inserted into adjacent sockets. A row of plugs in adjacent sockets represent a bus-bar.

Two pins of the plug are connected to the unit, and the third illuminates a lamp on the mimic diagram appropriate to the socket in which the plug has been placed. A view of the mimic diagram is given in Fig. 4. The fact that the appropriate unit is plugged into the correct socket is checked by the dimming of the lamps associated with the unit.

The panel on the left hand side of the desk illustrated in Fig. 1 controls the metering selection and range change for the master instruments. Each unit is identified by a three-digit number and the master meters can be connected to any of them by pressing-out the appropriate number on the selector panel. Having set up the system and adjusted the unit values the operator is able to determine the electrical quantities.

To set up a problem on the analyser it is first necessary to draw a system diagram and to mark on it all the relevant voltages, equipment ratings and component impedances. These data are then used to make a schematic system diagram on transluscent paper, which is placed on the mimic diagram table and registers with the indicating lamps. The units to be used in the study are next adjusted to the required values and are plugged upon the marshalling boards, correct selection being checked by the dimming of the indicating lamps on the mimic diagram when the appropriate unit is being metered. Finally, the operator at the control desk takes readings of all the electrical quantities and a second operator logs them on the schematic system diagram.

Fig. 1 Network analyser and control desk at the works of A. Reyrolle and Company, Limited.

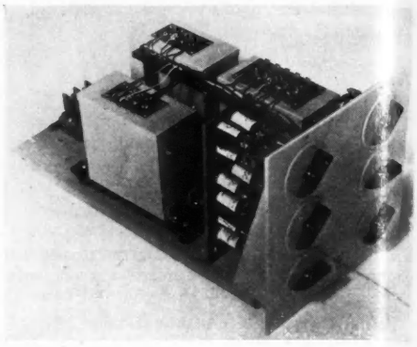


Fig. 2 Typical line unit of which there are 120 on the analyser. This unit is used for adjusting inductance and resistance.

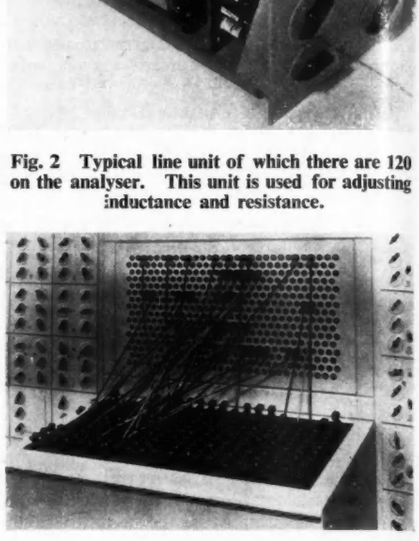


Fig. 3 Marshalling and plug board employed for setting up a network study.

Fig. 4 Mimic diagram. The lamps are dimmed when a unit has been correctly connected.

COAL-BURNING GAS TURBINE FOR LOCOMOTIVES

PULVERISED COAL AND FLY ASH PLANT

A considerable amount of experimental work has been in progress for some time in the laboratories of Bituminous Coal Research, Incorporated, at Dunkirk, N.Y., U.S.A., on the development of a coal-burning gas turbine suitable for use in a railway locomotive and last year, by courtesy of Mr. John I. Yellott, the Director of Research, and Mr. Peter R. Broadley, Assistant Director, we were enabled to inspect the equipment that has been developed there under their direction. They have recently submitted to the Locomotive Development Committee of Bituminous Coal Research a report covering the period from January 1 to December 15, 1953, and this report, slightly abridged, is reproduced below by permission of the Committee, together with a selection of the illustrations. In the original, the Locomotive Development Committee are usually referred to by their initials, "L.D.C." and the American Locomotive Company, of Schenectady, N.Y., who were closely associated with them in the work, as "ALCO." For convenience, these abbreviations have been retained.

In August, 1952, the Locomotive Development Committee completed a 750-hour coal-fired test of its 4,250-h.p. Allis-Chalmers gas-turbine power plant. After the results of this test had been evaluated, the American Locomotive Company advised the Committee that they wished to join with L.D.C. in continuing the project. ALCO proposed a three-part co-operative programme leading to further turbine tests with improved coal-handling and ash-separation equipment. When this proposal was presented to the Locomotive Development Committee at its January 8, 1953, meeting, the Committee voted unanimously to accept the proposal in principle, and authorised the chairman to negotiate a contract with the American Locomotive Company to implement the proposal. The contract was signed on March 6, 1953.

WORK PLANNED FOR 1953

The proposal presented to the Locomotive Development Committee by the American Locomotive Company was based on the following programme. The programme was divided into three parts, as follows.

L.D.C. accepted responsibility for developing methods for supplying the proposed locomotive with suitable coal – cleaned, dried, and properly sized – and for providing coal-handling equipment to conduct the forthcoming tests. Coal preparation was to be studied, to determine the most economical way of supplying coal suitable for use in gas turbines; and the coal-handling system at the Dunkirk Turbine Test Plant was to be revised to separate the drying and pulverising processes from the turbine coal-feed system.

ALCO and L.D.C. jointly assumed the responsibility and cost for completing the development of the equipment between the coal bunker and the turbine, including the coal pump, pulveriser, combustor, and ash separator. Ash separation equipment was to be developed intensively, to improve reliability and efficiency; new fly-ash separation equipment was to be built with necessary improvements; the gas turbine was to be simplified by removing the regenerator and providing necessary new piping and duct work; and instrumentation was to be provided for the continuous determination of separator and turbine performance.

ALCO agreed to accept the responsibility and costs of further development of the gas-turbine components, including electrical equipment, controls, and locomotive chassis. The necessary new blades for L.D.C.'s 4,250-h.p. Allis-Chalmers turbine were to be manufactured and installed; the rebladed L.D.C. turbine to be operated during the next test period to determine the adequacy of the new ash separator; and an investigation was to be made of the size and type of gas turbine most suitable for locomotive installation. The procuring of such a turbine for future work was to be the responsibility of ALCO.

WORK DONE DURING 1953

The Locomotive Development Committee have now accumulated more than 2,000 hours of coal-fired operating experience with full-scale gas turbines. Table I shows the principal characteristics of the coals which have been burned during 1,250 hours of Houdry unit operation and 930 hours of service in the 4,250-h.p. Allis-Chalmers turbine.

Volatile content has ranged from 20 to 40 per cent. and fixed carbon from 44 to 71 per cent., without causing any apparent combustion difficulties. Sulphur has varied from 0·2 to 4·0 per cent. with no adverse effects upon combustion or ash-removal equipment. Ash fusion temperatures from 2,350 to 2,750 deg. F. have caused no difficulty. The chemical nature of the ash has proved to be unimportant, since the normal constituents of coal ash are harmless to turbine materials.

Ash content is an important factor, and low-ash coals are obviously preferable since they reduce the load on the separating equipment. Heating value is significant only as it affects fuel cost, and as it is reflected in the required capacity of bunkers and feeding equipment. As long as 95 per cent. of the coal entering the combustor is finer than 100 mesh, combustor performance will be satisfactory. Moisture content and coal size are important because of their effect upon the capacity of the coal-handling equipment. It is essential that the coal be free-flowing when it reaches the locomotive bunker. Freedom from foreign matter is essential to prevent interruption to fuel flow or damage to feeding equipment.

The original goal of the Locomotive Development Committee was a completely self-contained power plant which would operate satisfactorily with any kind and size of bituminous coal. In the light of operating experience, it appears that little, if any, restriction need be placed on the kind of coal, but a more realistic requirement must be established for size and moisture content. Somewhere between the coal seam and the gas-turbine combustor, the coal must be reduced to a dry free-flowing powder containing not more than 5 per cent. of plus-100 mesh particles. When it reaches the locomotive, it should be in such condition that it can be handled entirely by pneumatic equipment without resorting to a mechanical conveyor.

The question of coal supply was discussed at length at the June 25, 1952, meeting of the L.D.C.'s Mechanical Advisory Group. Procurement of fine or pre-pulverised coal from the mines was advocated as one solution, while wayside preparation facilities appeared necessary to other members of the Group. In order to proceed towards a rational solution of this problem, a Sub-Committee on Coal Supply was appointed and authorised the distribution of questionnaires to the coal traffic managers of L.D.C. member railroads, asking them to list the preparation plants on their lines which are equipped to produce clean, dry, fine coal. They were also asked to list the important on-line consumers of pulverised coal, since the possibility exists that some large pulverised-coal plants might become coal processors in off-peak periods.

The replies to these questionnaires were

TABLE I. *Characteristics of Coals Burned in L.D.C. Gas Turbines*

Coal Identification	Pittsburgh Seam Bituminous		Lignite	Pocahontas
Source	Willow Grove*	Valley Camp	Australia	West Virginia
Volatile content, per cent.	39·5	36·3	45·5	20·4
Fixed carbon, per cent.	49·1	52·4	44·1	70·7
Moisture, per cent.	2·6	1·6	8·5	0·9
Ash, per cent.	8·8	9·7	1·9	8·0
Sulphur, per cent.	3·9	2·2	0·2	0·4
Higher heating value, B.Th.U. per lb.	13,210	13,430	10,100	14,446
Lower heating value	12,690	12,945	9,635	14,000
Ash fusion temperature, deg. F. (oxidising atmosphere)	2,440	2,680	2,750	2,350
Grindability, Hardgrove	68·5	65	—	110

* Selected by Mechanical Advisory Group as representative locomotive fuel.

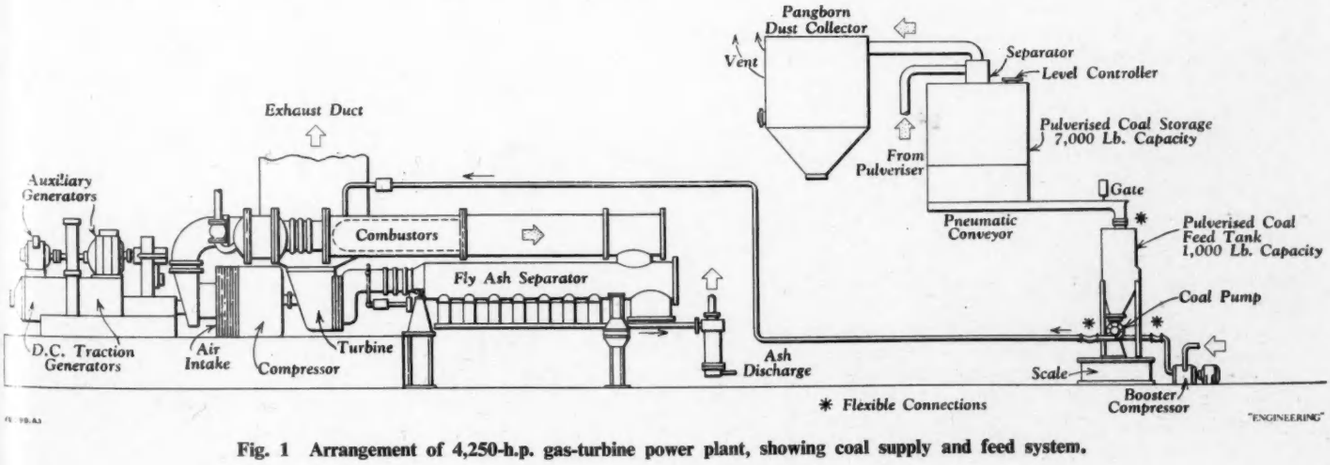


Fig. 1 Arrangement of 4,250-h.p. gas-turbine power plant, showing coal supply and feed system.

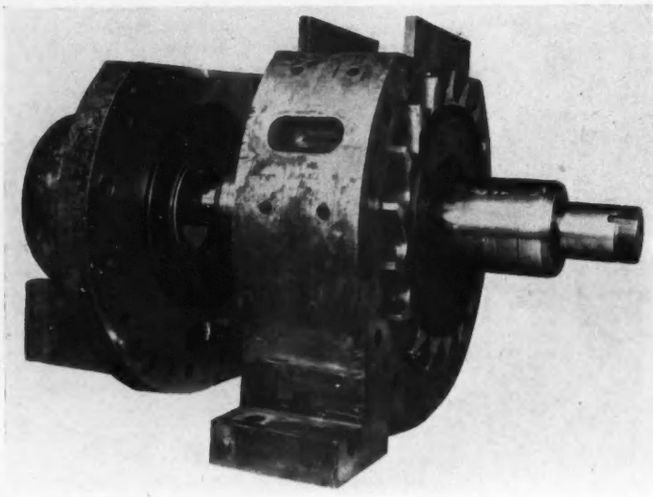


Fig. 2 Rotary coal pump consisting of a rotor turning in a casing and carrying pockets of coal from an atmospheric-pressure intake to a high-pressure discharge point.

amplified with data taken from the 1953 edition of the *Keystone Coal Buyers' Manual*. It was apparent that no significant quantities of coal suitable for direct use in gas turbines are being shipped at the present time. Virtually all modern fine-coal preparation plants can supply any required quantities of cleaned dried coal in the $\frac{3}{8}$ or $\frac{1}{4}$ by 0 size range. Equipment for producing and shipping finer sizes exists in only a few plants.

SIZE SUITABLE FOR PNEUMATIC CONVEYING

Ability to handle the coal on the locomotive with pneumatic rather than mechanical conveyors imposes limitations on size. L.D.C. experience has shown that coal which is $\frac{1}{4}$ in. in top size can be handled readily with Airslide pneumatic conveyors, as long as it contains a substantial percentage of −200-mesh particles. A quantity of $\frac{1}{8}$ in. by 0 air-cleaned coal, procured from a modern preparation plant, proved to be difficult to handle by this conveyor, because the −200-mesh fraction was only 3 per cent. When this coal was put through a hammer mill with $\frac{1}{4}$-in. screens, the resulting product was conveyed without difficulty, since the −200-mesh fraction had been increased to 34 per cent. Pulverised coal (98 per cent. −100 mesh, 83 per cent. −200 mesh) flows readily in the Airslide.

Since the hammer-mill reduction process is relatively inexpensive, $\frac{1}{4}$ in. by 0 coal, suitable for use with pneumatic conveyors, can readily be prepared from the widely available $\frac{3}{8}$ in. by 0 coal. It would appear that this $\frac{1}{4}$ in. by 0 dry coal would constitute a suitable gas-turbine fuel, provided that a pulveriser is used between the coal pump and the combustors. In one proposed system, the locomotive coal bunker would be loaded with dry coal in the $\frac{1}{4}$ in. by 0 size range; this coal would be fed from the bunker to the coal pump by means of a pneumatic conveyor. The coal would be pulverised under pressure as it is conveyed from the pump to the combustor. A high-speed attrition mill, of the type manufactured by the Riley Stoker Corporation, would be used. A design for an experimental pulveriser is being prepared for L.D.C. by the Riley Stoker Corporation.

The use of pre-pulverised coal, requiring no further treatment on the locomotive, would result in the simplest possible coal-burning gas-turbine locomotive. Pulverised coal can be produced at the mines and shipped in covered hopper cars, or it can be prepared in wayside facilities. The choice will depend upon the comparative overall costs.

COAL-PREPARATION EQUIPMENT AT DUNKIRK

The pulverised coal required during the forthcoming turbine test programme at Dunkirk will be supplied by the equipment which was used during the 750-hour test, rearranged to separate coal processing from direct connection with the turbine feed-pump. As Fig. 1 shows, the output of the Babcock and Wilcox pulveriser is delivered through a cyclone separator into a storage tank of 7,000 lb. capacity. The air from the separators is vented through the Pangborn dust collector, where the fines are caught. A screw conveyor returns these fines to the storage tank. An Airslide pneumatic conveyor is mounted in the bottom of the tank to transfer the pulverised coal to the feed tank (capacity, 1,000 lb.) which is supported on scales. The aerating feeder and rotary coal-pump are mounted beneath the coal feed tank, as shown.

These changes were made to add storage capacity to the test system, thus allowing the pulveriser to operate in a much more efficient manner, and also giving several hours of reserve coal supply. The addition of the scales supporting the pulverised-coal feed-tank will allow the rate of coal feed to the combustors to be determined accurately. The rotary coal-pump will be driven by a General Electric variable-speed direct-current motor, allowing very fine control of the rotative speed. A rheostat in the circuit provides for speed variation.

The 750-hours test showed that the L.D.C. rotary coal pump was a reliable device for delivering pulverised coal into a high-pressure (100 lb. per sq. in.) conveying air line. One pump was in service without requiring maintenance for 575 hours. The combustion equipment also operated in a satisfactory manner. The Operating Committee therefore decided to concentrate upon developing an improved fly-ash separator, since it was apparent that successful operation of a direct-fired coal-burning gas turbine depends entirely upon maintaining optimum separator performance at all times.

COAL PUMP TESTS

The L.D.C. rotary coal-pump consists of a rotor which turns within a casing, carrying pockets of coal from the atmospheric-pressure intake to the high-pressure discharge point. The type 5B pump, Fig. 2, has an 18-pocket rotor, 5 in. wide and 12 in. in diameter. The casing is formed by a centre ring and two side brackets, which contain the rotor bearings. The clearances between the rotor and the casing should not exceed 0·003 in. With this clearance, the leakage of air and coal is sufficiently low to allow the pump to function at pressures up to 150 lb. per sq. in. The power required ranges from 1 h.p. at minimum speed to 3 h.p. at maximum speed.

For any given air pressure, the capacity of the pump increases directly with speed up to approximately 50 r.p.m. Above that speed, the capacity falls off. As the pressure increases at any given speed, the capacity diminishes, since the amount of leakage increases directly with the pressure, reducing the amount of coal which can fall into the pockets. The capacity at any given speed and pressure is substantially greater with crushed coal than with pulverised coal. The capacity of the type 5B pump at 75 lb. per sq. in. discharge pressure is approximately 4,000 lb. per hour. At this feed rate, the turbine without the regenerator will produce approximately 3,600 shaft horse-power at an ambient air temperature of 80 deg. F.

COMBUSTION EQUIPMENT

The operation of the ring-supported all-metal combustors, Fig. 3, was satisfactory during the 750-hours test. They could operate over the entire turbine load range without needing to burn any oil as a pilot flame. The $\frac{1}{4}$-in. air gaps reduced ash accumulation to a satisfactory level, and very little distortion was evident at the conclusion of the test. The elimination of the regenerator allowed the flame path between the combustor discharge and the separator inlet to be increased by approximately 12 ft., so that the coal particles have additional time in which to burn before entering the separator.

The removal of the regenerator will alter the operating conditions of the combustors to a marked extent. At full load, without the regenerator, the temperature of the air entering the combustors will be approximately 480 deg. F. instead of 670 deg. F., which was the regenerator discharge temperature. The temperature rise in the combustors will be approximately 820 deg. F. instead of 630 deg. F. The lower inlet-air temperature and the higher temperature rise will subject the combustors to conditions which have not been previously encountered and some modifications may become necessary.

Venturi tubes have been installed in the combustor extensions so that the air flow through the two combustors and ash separators can be measured to ensure equal division. Ash samplers and temperature probes are being installed in the combustor outlets and at the inlets and outlets of the separators. Analyses of the ash samples collected at these points will enable an accurate evaluation to be made of the combustion at various points in the system.

ASH SEPARATION EQUIPMENT

During the first 178 hours of coal-fired operation of the Allis-Chalmers 4,250-h.p. gas turbine,

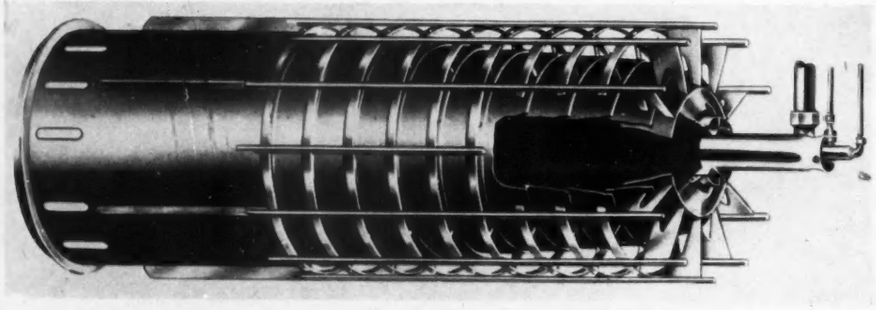


Fig. 3 Ring-supported all-metal combustor. This design can operate over the entire turbine load range without a pilot oil flame; ash accumulation has been reduced to a satisfactory level.

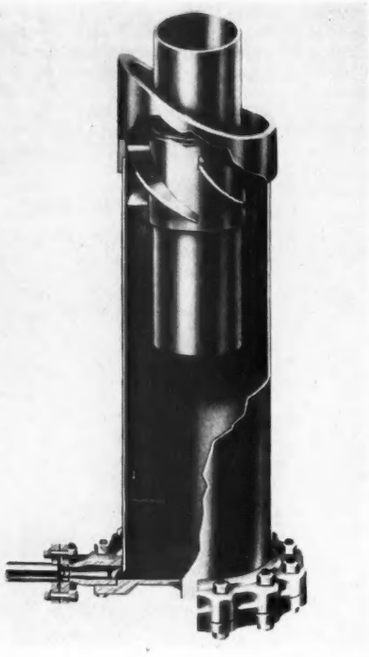


Fig. 4 Dunlab separator tube, 13 of which are used in the unit shown in Fig. 5.

no damage was done to the turbine blading by erosion. Ash samples taken from the exhaust stack showed no particles larger than 20 microns. Operation during this period was at half load or less, and the fly-ash separator apparently functioned at top efficiency during the entire period.

During the first 70 hours of the 750-hours test, a leak occurred within the separator, which allowed coarse ash to pass directly into the turbine. Serious erosion took place, and ash samplers were immediately installed in the turbine inlets to detect the presence of erosive ash. When full-load operation was resumed, following the repair of the leak, it was found that ash separation was quite inconsistent. Separator efficiency began to deteriorate after a few hours of operation, and the separator manifolds plugged frequently. No reason for this plugging could be found until, at the conclusion of the test, the separator was dismantled and obstructions were found in the blowdown manifold lines.

During the 1953 programme, attention was concentrated on improving the Dunlab separator tube and building multi-tube separation equipment of a new and improved design. The performance of each tube can be checked individually at any time, and instrumentation has been added to allow the overall performance of the separator to be checked continuously.

The original Mark I Dunlab separator tube has been subjected to intensive development, to achieve a new design which can operate over the entire turbine load range without losing efficiency. A positive method of determining blowdown air flow was also sought, since reduction in this flow was apparently the cause of the erratic performance of the separator during the 750-hours test.

In the process of developing a reliable test procedure, many different kinds of ash were used. It was finally decided to standardise on the " Fine Test Dust," which is made available by the AC Spark Plug Division of General Motors Corporation and used as a standard by the dust collector industry. This was selected because, as Table II shows, its size and density are close to those of the ash collected in the Houdry unit. In addition, it is available in large quantities.

TABLE II. *Size of Test Dusts Used in Developing the Mark III Dunlab Separator Tube*

Particle Size, Microns (25,400 Microns = 1 in.)	Philadelphia Electric Fly Ash	Houdry Unit Fly Ash	A.C. " Fine Test Dust "
0 to 10	40	44·4	53·5
10 to 20	8	32·0	15·1
20 to 40	17	17·4	14·3
± 40	35	6·2	17·1

Starting with the Mark I Dunlab tube, hundreds of tests were run at maximum turbine operating temperature, 1,300 deg. F. After a number of attempts to find a blowdown arrangement which could not be plugged by a large ash fragment, the annular blowdown shown in Fig. 4 was developed. The gap between the lower end of the tube and the bottom plate can be made as narrow as $\frac{1}{4}$ in. without reducing collection efficiency; the blowdown line is $\frac{3}{4}$ in. in diameter. Thus a particle big enough to plug the blowdown line cannot pass under the lip, but remains in the tube until it is reduced to a size small enough to allow it to pass under the lip and out through the discharge tube.

Tests were run with various modifications of this blowdown in which all of the dimensions of the tube were varied systematically. It was found that the original 27-in. tube length was satisfactory, while the optimum length of the cleaned-air discharge tube was found to be 10 in. The exact dimensions of the annulus were found to be relatively unimportant. The annulus, as well as the remainder of the tube, can be inspected at any time by removing the bottom cover. The radial blowdown shown in Fig. 4 proved to be slightly more efficient than a tangential outlet from the annulus.

After the optimum dimensions had been established, a final series of tests was run at 1,300 deg. F. with varying air flows and blowdown flows. At 1,500 cub. ft. per minute, which is the average air flow through each tube when the separator is in normal operation, the Mark III tube collected approximately 70 per cent. of the " Fine Test Dust," 83 per cent. of the Houdry unit ash, and 93 per cent. of the much coarser Philadelphia-Electric ash. With the Houdry unit fly ash, the cleaned air discharged from the tube contained less than 4 per cent. of + 10 micron particles. Microscopic analysis showed that most of the uncaught dust was finer than 5 microns.

The most important factor in the operation of the Dunlab separator tube is the maintaining of an adequate air flow through the blowdown pipe. As long as the flow is kept above 10 cub. ft. per minute, maximum efficiency will result. The loss in efficiency which occurred with the Mark I Dunlab tubes during the 750-hours test was apparently caused by gradual reduction of the blowdown flow below the 10 cub. ft. per minute required for maximum efficiency. To prevent a recurrence of this situation, attention was turned towards developing a method of measuring the blowdown flows without interfering with the operation of the tube. The use of a casting for the annular bottom offered an opportunity to determine the flow through the blowdown line by measuring the pressure drop from the elliptical section, where the line leaves the annulus, to the $\frac{3}{4}$ in. circular section at the connection to the blowdown pipe. A manometer connected across these taps gives a pressure drop which depends upon the quantity of air, or air and dust, flowing through the blowdown pipe.

NEW TWO-UNIT MULTITUBE SEPARATORS

The ash separation system used during the 750-hour test consisted of a battery of 26 Mark I Dunlab tubes mounted within a large pressure shell which was fabricated from Inconel X. Stainless-steel partitions were used to separate the incoming dust-laden gas from the outgoing cleaned gas. The blowdown lines from the Dunlab tubes were connected to two manifolds which were brought out through the shell. A serious leak occurred in one of the partitions separating the cleaned air from the dust-laden inlet air; this leak caused the first serious turbine-blade erosion. In addition, it was impossible to check the performance of individual tubes during operation, and removal of obstructions could be accomplished only by shutting down the plant and opening up the fly-ash separator.

To eliminate as many of these difficulties as possible, and to take full advantage of the features of the Dunlab tube, new multitube separators have been built in which the individual separator tubes are used as pressure-sustaining elements, and the large pressure shell has been eliminated. Since each of the two combustors discharges approximately 20,000 cub. ft. of air per minute during normal turbine operation, at temperatures up to 1,300 deg. F. and pressures up to 85 lb. per square inch abs., it was decided to construct two multitube separator assemblies, each using 13 Mark III Dunlab tubes. Fig. 5 shows a drawing of one of the two separators.

Each separator assembly consists of a 30 in. by 24 in. T through which the heated air and ash enter. The gases and ash then make a 90-deg. turn, guided by a deflector, through the 24-in. diameter vertical section of the T. A drop-out pot is placed beneath the T to catch heavy ash particles. The fine ash particles and air then make another 90-deg. turn, and enter the body of the separator.

The separator proper consists of a 28-in

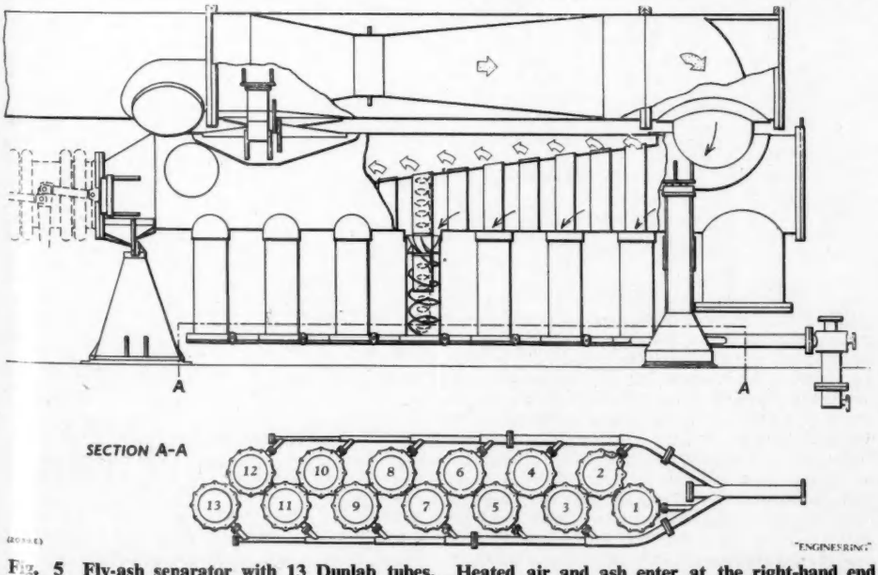


Fig. 5 Fly-ash separator with 13 Dunlab tubes. Heated air and ash enter at the right-hand end and then divide into the 13 tubes where, by centrifugal action, the ash is discharged through blowdown lines while the air passes up to the turbine.

diameter cylindrical section, divided into two parts by a diagonal slope sheet. The Dunlab tubes were welded to the lower part of the separator body, and the slope sheet causes the ash-laden air to turn downward and enter the individual tubes. The cleaned-air discharge tubes are inserted through the vaned sections which cause the dust-laden air to spin as it enters the tubes. As shown in Fig. 5, the ash particles in the spinning air stream are thrown by centrifugal force towards the wall of the separator tube. The particles are then carried out through the blowdown line while the cleaned air spins up through the discharge tube and proceeds to the turbine inlet. The discharge tubes are welded to the slope sheet, but are free to slide through the vaned sections, thus allowing the necessary flexibility to permit the discharge tubes to expand and contract freely. The slope sheet is welded on both sides to the upper and lower sections of the separator body.

Because of the relatively small diameter of the separator body, the stresses in the shell are low enough to permit the use of Incoloy instead of the Inconel X which was required on the original large-diameter pressure shell. To give the necessary strength to the lower part of the shell, which is cut away to allow the air to enter the Dunlab tubes, ¾ in. thick Incoloy was used for the first 7 in. of each separator tube. The remainder of the tube is made from stainless steel, salvaged from the old separator. The annular discharge sections and cover plates of the tubes were cast from stainless steel.

Each separator is supported upon two pedestals. At the turbine inlet end it is bolted rigidly to a pedestal which extends upward from the platform. The inlet end of each separator is supported by, but not bolted to, a floor-mounted pedestal. The weight of the separator is supported by rollers, which permit the shell to expand away from the turbine. The combustor casing and extension are bolted rigidly to the separator inlet flange, so they also tend to move away from the turbine as the unit heats up. Since the temperatures and coefficients of expansion of the various components are different, they will expand at different rates; this variation is accommodated by expansion joints at the combustor inlets. The end flanges shown in Fig. 5 can be removed to permit inspection of the combustors and the inlet sections of the separators. A large inspection port is located near the outlet of each of the two separators. Through this opening, the discharge tubes of the separators can be inspected.

The blowdown lines from the 13 Dunlab tubes in each unit will be connected through the manifolds to an ash concentrator. A flow of cold air can be established through the manifold line if necessary to keep it clear under all operating conditions. In addition, the manifold line has been so designed that it can be inspected during each step of the assembly process. To equalise the blowdown flow from all of the separator tubes, provision has been made to vary the area of the blowdown lines after the measuring section has been passed. It will be seen from Fig. 5 that tubes 1 and 2 are nearest to the separator inlet and to the discharge end of the manifold. At the other end of the separator, the tubes numbered 12 and 13 are at the far end of the inlet section and also are farthest away from the discharge end of the manifold. Thus the pressure drop causing the flow through the blowdown lines of tubes 1 and 2 will be considerably greater than the pressure drop causing the blowdown flow out of tubes 12 and 13.

To counteract the natural tendency for the first tubes to supply most of the blowdown flow, while the last tubes supply virtually none, the bottom castings have been counter-bored and stainless-steel bushings of five different inside diameters have been provided. Bushings with minimum inside diameter will be installed in the lines from tubes 12 and 13. The pressure drop across the metering sections of the blowdown lines will continue to be a measure of the total amount of blowdown flow. Further reduction in bushing diameter can be made if necessary to equalise the flow from the first and last tubes. If one of the blowdown lines becomes obstructed for any reason during operation, the pressure drop across the metering section of that tube will fall below the normal value, and the manometer will indicate which tube is in difficulty. Another method of determining whether all blowdown lines are working will be provided by measuring the temperature of each line. When the temperature of any line becomes different from the temperatures of the other lines, plugging or excessive flow will be suspected and investigated.

The two manifolds on each of the separator units will be combined and brought into a blowdown ash concentrator. The cleaned air from the concentrators is available for use in coal drying if it is needed. The concentrated ash will be discharged into the collector. A frequent cause of difficulty during the 750-hours test was erosion in the ash discharge lines. The velocity of the air conveying the ash will be reduced during the forthcoming test to eliminate this erosion.

INSTRUMENTATION

The instrumentation of the test plant has been extended and improved. Air-flow meters have been installed in the compressor intake line and in the two combustor extension sections. Ash-sampling stations have been added at the separator inlets, and two methods have been developed for detecting the presence of erosive ash at the turbine inlets. Pressure taps have been provided at four points on the inlet and outlet sections of each separator shell, so that an estimate can be made of the distribution of air flow among the separator tubes. The use of blowdown flow manometers in the ash-discharge line from each separator tube has been mentioned previously. Temperature probes are installed at the outlets of the two combustors and at the inlets of the two separators. Temperatures on each of the 26 separator-tube blowdown lines will be recorded on a Brown Electronik pyrometer.

Air for the compressor continues to be drawn in through a screened intake above the roof, but the straight section leading into the building has been altered to house a standard Venturi air flowmeter, with a throat 27 in. in diameter and 13 in. long. Four manometers will measure the pressure drop from the inlet to the throat. This will enable the air flow into the system to be measured continuously, and at the same time reduce the intake pressure loss.

In the new system, the air leaving the compressor is divided into two streams which flow through the individual combustors and separators to the two turbine inlets. There is no connection between the two sides of the system from the compressor-discharge plenum chamber to the turbine-inlet space ahead of the first row of cylinder blading. Venturi sections (throat diameter 18 in., length 9 in.) have been installed in the combustor extensions, as shown in Fig. 5, so that the air flow through the two halves of the system can be measured, to determine whether it is equally divided. If any major inequality is found, a damper can be installed in the plenum chamber ahead of the combustors.

SEPARATOR PERFORMANCE

The determination of the separator performance will be of the utmost importance during the coming test. Additional ash samplers have been provided at the inlet to each multitube separator, while the samplers at the two turbine inlets have been retained. Ash samples will be taken at these two points at frequent intervals, to determine, by the relative weights of the collected samples, how efficiently the separators are functioning. In addition, frequent particle-size analyses of the dust entering the turbine will be made. The 750-hours test showed that there was a direct correlation between the amount of ash entering the turbine and the particle-size distribution. Heavy ash loading at the turbine inlets was invariably accompanied by a high percentage of + 10 and + 20 micron ash particles. Samples of the ash entering the turbine will also be examined frequently under a high-power microscope to estimate ash particle size without waiting for the results of the elutriator size analysis. Microphotographs of these ash samples will also be made, using a Polaroid 60-second developing film pack to speed up the process.

EROSIVE ASH DETECTORS

Early in 1953, a project was initiated at the Armour Research Foundation in Chicago to establish new methods of determining whether erosive ash was being admitted to the turbine. The principal criterion was speed of action, since the 30-minute sampling periods used during the 750-hours test were much too slow to detect sudden changes in separator performance. Two methods were selected, the first utilising the change in electrical resistance of a sample exposed to erosion in the turbine inlet stream, while the second proposed to use irradiated S-590 alloy, containing Cobalt 60, as a tracer to detect erosion.

The electrical resistance method was first tried at atmospheric temperature, and it was found that the resistance of a strip of platinum would change at a measureable rate when coarse ash was allowed to impinge upon it. To apply this method at the turbine inlet, it was necessary to compensate for temperature changes. This was accomplished by setting up a simple bridge circuit, in which one side of the bridge was the erosion-test specimen, while the other side was an identical piece of platinum, shielded from ash impingement. This method was found to be feasible at atmospheric temperature, and tests were then started at 1,300 deg. F. It was found that, at this temperature, platinum could be replaced by kovar, an inexpensive and readily available alloy. Coarse ash impinged upon the kovar specimen at 1,300 deg. F. causes its resistance to change six times as rapidly as fine ash impinged at the same velocity. This difference is readily detected with electrical instruments and translated into relative erosiveness.

Successful use of radioactive tracer techniques in detecting the presence of extremely minute quantities of irradiated metal suggested that this idea might be adapted to a turbine erosion detector. Preliminary tests of a small irradiated target of S-590 showed that the metal removed by an ash-laden air jet in one minute could be detected because of the radioactivity of the Cobalt 60 in this alloy. Further analyses showed that it would be feasible to use one or more irradiated S-590 blades in the turbine and to determine their erosion rate by sampling the ash in the exhaust stack.

Because of the necessity for shielding the turbine, the irradiated blade method was discarded in favour of a less direct but simpler system. Samples of the ash entering the two turbine inlets will be impinged at high velocity upon small targets of irradiated S-590. The air stream will then be led through a slowly moving tape of filter paper where the ash and removed fragments of metal will be caught. A scintillation counter will scan the tape continuously and the radioactivity of the observed portion of the tape will be indicated in terms of " counts per minute." If the ash taken from the turbine inlet air stream is non-erosive, the counting rate will be determined by the environment around the apparatus. If, on the other hand, even the slightest amount of irradiated S-590 appears on the filter tape, the counting rate will go up in direct proportion to the amount of metal presented each minute to the counter. If the rate of erosion rises beyond a pre-determined limit, the electronic equipment will sound an alarm to warn the turbine operator. The rate of erosion can also be recorded on a Brown Electronik instrument.

The particular advantage of the radioactive method is its speed and directness. Less than one minute will be needed to detect the presence of erosive ash, and the actual amount of metal removed can be calculated.

To be continued

HER MAJESTY'S YACHT "BRITANNIA" *

By Sir Victor Shepheard, K.C.B., R.C.N.C.

Concluded from page 541

The bridge front is terraced to provide deck space at shelter-deck level for an Admiral's bridge and at bridge-deck level for a Royal bridge. These are design requirements, but the problem of wind protection on these bridges is in consequence much more difficult to solve than with the conventional cliff front. In particular, it was necessary to provide the maximum wind protection on the Royal bridge. The configuration of structure, particularly the forecastle, sunk between high bulwarks, and the open deck at shelter-deck level, leads to a strong back draught on this bridge. To obtain a good view forward from the Royal charthouse the height of bulwarks on the Royal bridge was limited to 3 ft. 10 in. On these bulwarks are fitted portable glass screens, 1 ft. 9 in. high, which can be quickly hinged down and stowed against the bulwark when not in use.

Wind-tunnel experiments at Teddington on a model of the bridges showed that the bulwarks and screens alone were insufficient to prevent the wind striking the structure at the back of the bridge and descending in strong eddies on to the deck of the Royal bridge. Consideration was then given to fitting a wind alley to trap the descending air and guide it to the sides of the ship. Experiments were conducted to find the optimum position of such a screen and it was finally fitted 3 ft. 6 in. from the superstructure and with a height of 3 ft. 10 in. Extensions at each side, of full height between decks, were fitted to the front of the Royal chart house to protect the entrances from the high wind velocities in the wind alley.

ACCOMMODATION

Accommodation for the Royal party and staff is aft and for the ship's company forward. The Royal apartments are on the shelter deck between the main and mizen masts, with a verandah at the after end leading on to a sun deck. The deck of these apartments is 2 ft. higher than the general shelter-deck level, so that the external fore and aft gangways are well below the windows of the Royal apartments.

The main staircase from the Royal apartments on the shelter deck leads to a vestibule on the upper deck, about which are grouped the State apartments. At either side of the vestibule are Her Majesty's and His Royal Highness's sitting rooms. The dining-room, drawing-room and ante-room extend the full width of the superstructure without obstruction from pillars. Sliding screens are fitted at the entrance to the ante-room and between the ante-room and the drawing-room. They can be folded back when required to provide a large reception space from the after end of the drawing-room to the foot of the main staircase.

The main staircase continues down from the upper deck to the main deck, in the vicinity of the main entrance ports. The Household and guest cabins, sitting-rooms and cloak rooms are on this deck. The Royal staff is accommodated on the lower deck. The crew of 21 officers and 250 men is accommodated forward in a manner generally in accordance with Service practice.

In the interests of economy, use has been made as far as possible of furniture from the Victoria and Albert and of new pieces supplied for use in S.S. Gothic for the Commonwealth tour. Messrs. John Brown appointed Messrs. A. McInnes Gardner and Partners as their decorative architects for this work. Because of its importance from the standpoint of current British decorative art it was considered desirable to have the advice of a second specialist in this field and Sir Hugh Casson was appointed as consultant to the Admiralty.

LAYOUT AS HOSPITAL SHIP

The Medical Director General of the Navy was consulted about the requirements for the vessel as a hospital ship. It was thus possible to proceed with the designs for a hospital ship and a Royal Yacht concurrently, so that the conversion could be made in the most economical manner. Relatively little alteration to existing structure and equipment will be required in the unhappy event of war making the conversion necessary.

The wards, which will accommodate 200 patients, will be located in the after part of the ship. Most of the patients will be medical and surgical cases requiring normal hospital conditions, but provision has also been necessary for zymotic cases and those suffering from tuberculosis. Tuberculosis cases requiring "fresh-air" beds will be accommodated on part of the verandah, while others suffering from this disease will be berthed in wards in the space now occupied by the Royal bedrooms. The remaining wards, including the cabins and ward room for sick officers and cabins for a few female patients, will be sited in the other Royal apartments and in spaces now allocated to members of the Royal Household and Staff.

The operating theatre, with its annexes and its adjacent steriliser and anaesthetic rooms, will be on the lower deck, where there will also be an ophthalmic room, a physiotherapy room, a pathological laboratory and an X-ray room with adjacent dark room. Full facilities for dental treatment, including a laboratory, will be located on the main deck.

GALLEYS, COLD AND COOL ROOMS, ETC.

Separate galleys are provided for the Royal party, the ship's officers and the ship's company, all grouped amidships on the upper deck. The exhaust ventilation trunks from these spaces are led up inside the funnel. Ranges, grills and ovens are all-electric, steam being supplied only for steam cookers and boiling coppers. The Royal galley provides service for the Royal dining-room and also for the Royal staff messes, the food for the latter being conveyed by lift to the lower deck. This galley is of such a size and is so equipped that, for hospital ship service, it can provide suitable food for all the patients, although a little additional equipment will be required to cater for any Asiatics who might be embarked. Lifts from the crew's galley take food directly to the main and lower decks for distribution to the various crew's messes.

Four main cold and cool rooms are provided for the storage of provisions. An ice-making cabinet in the cooling machinery compartment makes 500 lb. of ice per day, and incorporates storage capacity for 1,000 lb. The cooling machinery for the cold and cool rooms and for ice-making consists of two electrically-driven cooling plants using Freon 12/Arcton 6 as the refrigerant, each machine being fitted with independent control valves. The cold and cool rooms, as in modern naval practice, are refrigerated by air recirculation. Normal brine arrangements are provided for the ice-tank.

AIR CONDITIONING, VENTILATION AND HEATING

An air-conditioning system serves the after accommodation spaces which, in the hospital ship rôle, will be the hospital section of the ship. This system has been designed to maintain an inside condition of 85 deg. F. dry-bulb and 71 deg. F. wet-bulb when the outside atmospheric condition is 88 deg. F. dry-bulb and 80 deg. F. wet-bulb. Under cold-weather conditions the installation will maintain an inside temperature of 70 deg. F. when the outside temperature is 30 deg. F. The refrigerating machinery for air conditioning comprises two steam-jet vacuum-type plants, each capable of extracting 1,000,000 B.Th.U. per hour under tropical conditions. The cooling medium is chilled water, circulated to 13 air-conditioning units. The heating medium is warm water, circulated to the units through heating calorifiers. Automatic temperature and humidity controllers are provided for each section.

To keep noise levels to a minimum, fans and units have been grouped in acoustically-lined chambers and, where necessary, trunking has also been acoustically lined. No recirculation of conditioned air is used in the system, fresh filtered air being supplied whether cooling, heating, or mechanical ventilation is in operation.

The forward accommodation spaces for the ship's company are ventilated by fan supply and exhaust; they are heated by gilled-tube heaters. Galleys, bathrooms, workshops, etc., are ventilated with air at atmospheric temperature by fan supply and exhaust. A separate small refrigerating unit is fitted to air-condition the wireless offices.

Every effort has been made to ensure that the ventilation system is fitted with the least possible detriment to the watertight integrity of the ship. All ventilation trunking is arranged so that no main sub-division bulkhead is pierced below the main deck. To preserve the watertightness of the platform deck the ventilation trunking from hold compartments is watertight between the platform and lower decks, except when the trunking leads to a fan on the platform deck. In such cases a watertight slide valve is fitted to the trunking at platform deck level. Above the main deck the fire division bulkheads are fitted with valves on each side where pierced by ventilation trunking. Watertight slide valves are also fitted to trunking piercing the foremost and aftermost sub-division bulkheads.

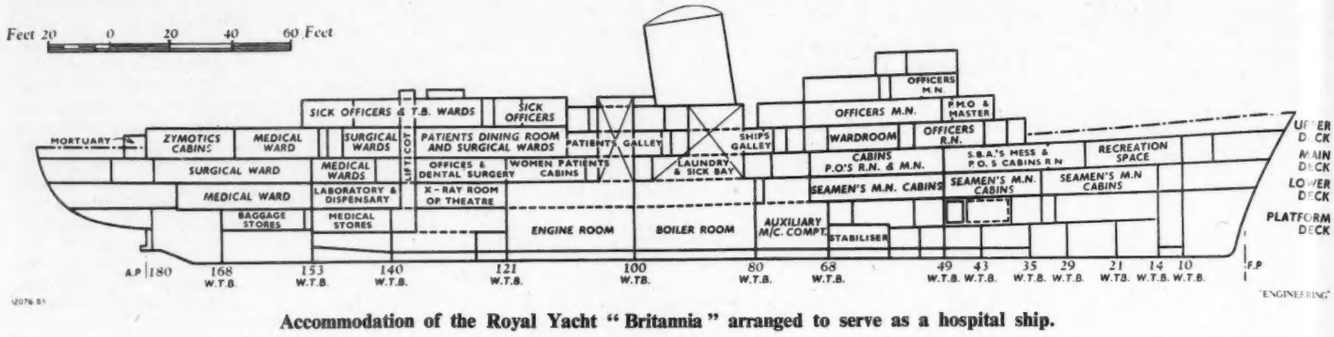
PUMPING AND WATER SERVICES

Three 70 tons an hour motor-driven bilge pumps are fitted, one in each of the three main machinery spaces, one 70-ton pump aft of the machinery spaces and one 20-ton pump forward. The 70-ton pump in the boiler room is an emergency submersible pump with controls geared to above the main deck. Each pump can take suction from the sea, from the compartment in which it is situated, or from the main suction line. Discharge is overboard or to the fire main. The main suction line runs throughout the ship, being well above the keel outside the machinery spaces.

The fire main runs throughout the length of the ship, with hose connections within the ship and on the weather decks. Foam arrangements are provided for fire-fighting in the machinery spaces. An automatic sprinkler system is fitted throughout the after accommodation. Sanitary services are supplied from the fire main through reducing valves.

Allowance has been made for a higher rate of consumption of fresh water for domestic purposes than is usual in H.M. ships. Tank stowage for 195 tons of fresh water is provided, and there are two evaporators with a total distilling capacity of 120 tons per 20-hour day. A 20 tons a day feed-water distilling plant is fitted in the engine-room to provide make-up feed-water. Fresh-water storage tanks are fitted at each end of the ship. Two separate fresh-water pressure supply systems are provided, one forward and one aft, and can be interconnected if required. The water is chemically treated

* Paper read at the Spring Meeting of the Institution of Naval Architects, held in London on April 7 to 9, 1954. Abridged. The discussion on the paper was reported in ENGINEERING last week, on page 522.



Accommodation of the Royal Yacht "Britannia" arranged to serve as a hospital ship.

by the injection of chlorine into the filling main. The water is pumped from the storage tanks through fine-mesh filters to the pressure tanks and then to the fresh-water main through carbon dechlorinators. Separate hot fresh-water systems are also fitted forward and aft, with provision for interconnection. Each system is heated by a 300-gallon steam calorifier with a heating capacity of 3,000 gallons per hour.

FUEL OIL SYSTEM

Capacity is provided for 490 tons of fuel oil and 20 tons of Diesel oil. The tanks are situated mainly in the double bottom, although deep tanks are located fore and aft of the machinery spaces. Settling tanks are provided, port and starboard, in the boiler room. Filling connections are fitted amidships and forward, and fuel may be embarked on either side of the ship. The forward position will be used mainly for replenishment at sea. It is expected to achieve a fuelling rate of 250 tons an hour at sea.

An oil fuel suction main runs the full length of the tanks with branches to each tank. The filling line is connected to this main in the boiler-room and the tanks are filled through the suctions. Oil can be transferred from the forward to the after tanks and *vice versa*, to correct heel or for any other purpose. It cannot, however, be transferred from the port to the starboard tanks in the same group.

SEWAGE SYSTEM

Two entirely separate sewage and waste water systems are fitted, one forward and one aft. This will enable the system aft to be completely shut down when it is not required. Each system discharges to a sewage tank which is pumped out by either of two pumps, operated by float control. Two overboard discharges are provided, one on each side of the ship for each system. Either pump may discharge on either side. The sewage tank may be by-passed, if necessary. To reduce the frequency of pumping out the tanks when necessary, arrangements have been made for the disposal of waste water from baths, etc., directly overboard in harbour.

ANCHORS AND CABLES

The anchor and cable equipment consists of three 60-cwt. Admiralty-pattern stockless bower anchors (one spare), 270 fathoms of $1\frac{7}{8}$ in. forged-steel stud-link cable, one 20-cwt. Admiralty-pattern stockless stream anchor, and one 300-lb. Danforth kedge anchor. Recessed stowages are provided for the bower anchors. A twin-headed electrically-driven capstan and cable gear is fitted forward, driven by a 64-h.p. motor. The capstan is capable of exerting a pull on either cable, but not simultaneously, of 20 tons at 25 ft. per min. and hoisting slack cable equivalent to a pull of $1\frac{1}{4}$ tons at 40 ft. per min. The gear is capable of exerting a pull greater than 48 tons, but the clutches are designed to slip at a load of 50 tons. A warping pull of 15 tons at 33 ft. per min. is possible from either capstan barrel, and the brake gear is capable of holding 30 tons without creeping. An electrically-driven capstan is fitted aft for working $4\frac{1}{2}$ in. steel wire hawsers.

BOATS AND LIFE-SAVING EQUIPMENT

The boat complement consists of a 40-ft. Royal barge, two 35-ft. medium-speed motor boats, a 32-ft. motor cutter, two 27-ft. jolly boats (sea boats), two 16-ft. fast motor dinghies, and two 14-ft. sailing dinghies. The Royal barge was originally built in 1938 for use with the Victoria and Albert. It is a hard-chine boat fitted with triple Diesel engines and was last used at the Naval Review at Spithead in June, 1953.

In addition, the Britannia carries 18 life rafts of a new design, recently introduced into the naval service. They are of a self-inflating type, stowed on board in valises, and weigh with stores about 440 lb. each. The raft consists of an oval-shaped float with centre thwart and floor and an arched canopy, all of which are inflated by CO_2 under pressure. Each raft comfortably holds 20 persons. The raft in its valise is thrown overboard, secured to the ship by static line. If the line is pulled the raft inflates automatically breaking the lacing of the valise. The rafts inflate the right way up, irrespective of how they enter the water.

The six larger power boats are stowed in gravity davits. The 40-ft. and 35-ft. boat davits are fitted for power hoisting and lowering and emergency gravity lowering, and the 32-ft. and 27-ft. boat davits for power hoisting and gravity lowering. A special reeling device has been designed by the davit manufacturers to ensure that the falls lower easily under no-load conditions without the need for overhauling. This device consists essentially of driving the wire mechanically over the pulleys at each davit head.

DERRICKS AND HOISTING GEAR

Two large derricks are provided midships, one each side at the base of the funnel. To preserve appearance, a scheme has been devised whereby the funnel has been used as a derrick post. Topping lifts are taken to eye plates which hinge back inside the funnel when not in use, when portable cover plates preserve the outward funnel shape. Power lifting and topping is provided by two winches, each with a working load of two tons. The derricks may be used for storing ship, or as an alternative method of lifting out the motor and sailing dinghies, or for the removal of boat engines from boats in the water or in their davits. Spare motor-boat engines are carried on board in a motor-boat engine workshop so that engines may be changed at sea with the boats in the davits.

At the after end of the forecastle, portable storing davits are fitted, port and starboard, having a working load of 7 cwt., power being provided, if required, from the capstan. A space for a motor car is provided on the shelter deck abreast the 40-ft. barge. The car is carried on a transporter running on an athwartships track-way sunk into the wood deck and terminating under thr 40-ft. barge davits.

STABILISERS

Denny-Brown single-fin stabilisers are fitted in a hold compartment immediately forward of the main machinery spaces. The specification for the gear called for power to stabilise a roll of 20 deg. out to out, reducing it to 6 deg. out to out at ship speed of 17 knots. The fins, which are retractable, are 4 ft. 6 in. wide, with outreach from the hull of 9 ft. 4 in. and an area of 42 sq. ft. each. They can operate at the full ship speed of 22 knots at the maximum fin angle, which is 20 deg. The fins are run out, rotated and retracted by an electro-hydraulic system which is capable of being controlled from the bridge. The main controlling motor is a $37\frac{1}{2}$ brake horse-power unit and the servo-motor a 10 brake horse-power unit.

NAVIGATION AND COMMUNICATIONS

The vessel is equipped with an Admiralty (Sperry-type) gyro-compass installation. The master gyro is situated on the platform deck under the bridge, with repeaters to the Royal chart house, compass platform, wheelhouse, bridge wings, steering compartment and emergency conning position. An ornamental binnacle, originally from the Royal George, has been taken from the Victoria and Albert, fitted with a gyro repeater and mounted on the sun deck aft. Magnetic compasses and associated equipment to Admiralty standards are fitted on the compass platform, in the wheelhouse and at the emergency conning position. The wheel from the racing yacht Britannia is used in the wheelhouse and has been suitably inscribed.

In addition, the following navigational aids are installed: direction finder for general use, Decca navigator, Loran, navigational radar, commercial-type electric log, and echo sounder. Four wireless transmitting sets and their associated receivers are provided. A link is provided for ship-to-shore telephone communication and on certain telephones speech can be scrambled for security purposes if required.

With the number of sets to be operated, whip aerials have to be used in addition to roof aerials. The whips are situated on the bridge and on the sides of the funnel. As a matter of expediency the decorative caps on the tops of the masts are aerials. For the conduct of State business on board, cryptographic equipment is fitted in the cypher office. Facsimile transmission is also installed. Sound reproduction equipment is fitted throughout the ship, with the choice of three programmes.

MAIN AND AUXILIARY MACHINERY

Because of urgency, the choice of main machinery was limited to the selection of a modern well-proven unit which could be produced in a reasonably short time. It was important for both the Royal Yacht and hospital ship rôles that noise and vibration should be kept to the absolute minimum and this ruled out Diesel machinery, which was otherwise attractive from the point of view of endurance.

A set of geared-turbine machinery of power similar to that required for the Royal Yacht had been designed by John Brown and Company, Limited, with the co-operation of the Parsons and Marine Engineering Research and Development Association (Pametrada), and fitted in the cross-channel steamers Arnhem and Amsterdam. This set of machinery was taken as the basis for the machinery designed for the Britannia. Geared steam turbines were accepted as being the most suitable.

The machinery was developed from this basic design, taking into account the following requirements:

(*a*) the machinery to be capable of running at full power in both tropical and arctic climates;

(*b*) good habitability in the machinery spaces, in particular under tropical conditions;

(*c*) arrangements to meet normal Service standards for steaming under gas attack conditions to be incorporated as far as possible;

(*d*) special precautions to be taken as far as possible against shock damage from underwater explosions;

(*e*) the machinery to be as smooth-running and silent as possible, and all avoidable vibration to be eliminated at its source. Resilient mountings have been fitted beneath the Diesel generator to reduce structure-borne vibration.

The main boilers are so arranged that either boiler can steam both the port and starboard engines. The electrical generating sets with their auxiliaries are situated in a separate generator room at the forward end of the machinery spaces, as far from the State apartments as practicable.

The main machinery consists of two sets of turbines and gearing, each set comprising one H.P. turbine and one L.P. turbine in which is incorporated the astern turbine, all constructed by John Brown and Company (Clydebank), Limited. Single-reduction hobbed and shaved gearing is fitted, driving the shafts at 285 r.p.m. when the maximum power of 6,000 shaft horse-power per shaft is being developed. Full-power revolutions of the H.P. and L.P. turbines are 4,910 and 3,550 r.p.m., respectively. The condensers, which are of the two-flow type, are underslung beneath the L.P. turbines and are supplied with circulating water by electrically-driven pumps with a maximum capacity of 10,000 gal. per minute for each condenser. A closed-feed system is fitted, using an auxiliary condenser in the boiler-room for harbour steaming conditions.

Steam is generated from two main boilers, each having a capacity of 75,000 lb. per hour at a pressure of 300 lb. per square inch and a temperature at the superheater outlet of 660 deg. F. The combustion air is trunked to the boilers and is drawn by electrically-driven forced-draught fans from a plenum space at the base of the funnel, into which the exhaust ventilation from the boiler-room is discharged. The exhaust gases from the boilers are extracted by electrically-driven induced-draught fans and discharged through grit arresters to the atmosphere. At full power, the gases leave the funnel with a velocity of about 110 ft. per second and a temperature of 400 deg. F.

It is essential for the efficient operation of the grit arresters, and to keep the funnel discharge well clear of the ship, that a high efflux velocity of the exhaust gases be maintained under varying power conditions. This is obtained by hydraulic control from the boiler-room platform of the inlet flaps to the grit arresters, which allows the number of arresters in use to be adjusted to suit the power.

An auxiliary boiler is installed to meet harbour requirements. It has an evaporating capacity of 20,000 lb. per hour at the same steam conditions as the main boilers, and can be used to augment the main steam supply. The main and auxiliary boiler feed pumps and the main engine auxiliaries are electrically driven. Two salt-water evaporating and distilling plants, each having an output of 60 tons per day, are fitted in the generator room and a 20-tons a day feed-water evaporator is sited in the engine-room for make-up purposes.

The ventilation and general conditions in the machinery spaces during trials were most satisfactory and well repaid the close attention given to these matters during the design stage. The engine-room is ventilated by two axial-flow and two centrifugal supply fans with a total output of 30,000 cub. ft. per minute and three axial-flow exhaust fans with a total exhaust of 32,000 cub. ft. per minute.

Air to the boiler-room is supplied by two axial-flow fans of 10,000 cub. ft. per minute each, and the generator room has a fan supply and exhaust of 15,000 cub. ft. per minute.

The steering gear is of the electro-hydraulic type, with two separate motor-driven variable-delivery pumps, either of which is capable of actuating the rudder under maximum torque conditions. The pumps are telemotor-controlled from the wheelhouse and by mechanical control in the steering-gear compartment. A separate hand-operated variable-delivery pump is available for emergency operation of the gear.

FUNNEL

It was desired that the funnel should have a pleasing appearance, that the decks should be free from smoke and funnel gases, and that the funnel paintwork should not be discoloured by smoke and gases eddying in the vicinity of the funnel top. As was to be expected, the most efficient funnel suggested by the wind-tunnel tests at the N.P.L. was unacceptable on account of height and shape of top. A major factor in producing a clean ship is the high efflux velocity of the gases in the full-power and part-power conditions. Efflux velocities in this ship are high and vary between 110 ft. per second at 12,000 shaft horse-power to 80 ft. per second at 1,000 shaft horse-power. A gutterway is fitted round the top of the funnel so that rain water can be drained away to prevent discoloration of the funnel sides. Exhausts from the galley, laundry and lavatory fans, and from the Diesel generator and incinerator, are led up inside the funnel.

ELECTRICAL INSTALLATION

The dynamo load at sea was estimated to be approximately 730 kW and the harbour Diesel load about 250 kW. The following generators are fitted for lighting and power supplies: three 500-kW steam turbo-generators, one 270-kW Diesel generator, and a 60-kW emergency Diesel generator. Consideration was given to fitting an alternating-current installation in accordance with recent Admiralty policy for H.M. ships, but once again the time factor precluded the possibility of obtaining delivery of new generators in time to avoid delay in completion of the ship. Furthermore, most of the main machinery auxiliaries were planned for electrical drive; the economic operation of these auxiliaries, including boiler-room fans, depended upon the availability of a speed control range not obtainable with standard-type alternating-current motors. The direct-current installation is at a constant voltage of 225, all permanent wiring being on the two-wire two-conductor system, with both poles insulated.

The three turbo-generators are fitted in the generator room and any two are capable of supplying the full seagoing load. The 270-kW Diesel, also fitted in the generator room, is capable of meeting the harbour load or the salvage load when steam is not available. To allow for maintenance of this Diesel generator in harbour when necessary, steam can be supplied from the auxiliary boiler to run one of the turbo-generators to cover the harbour load. The generators feed into a main switchboard in the generator room. Distribution from the main switchboard to the various circuits is by double-pole circuit-breaker, the switches and fuses following normal practice.

The emergency Diesel generator, together with its own starting battery, is situated in a shelter-deck compartment. It feeds into a switchboard adjacent to the generator and in an emergency will supply vital services such as radio, salvage pumps, emergency lighting and the power-operated water-tight doors.

Alternating-current services are supplied by two motor generators of an output of 35 kVA at 230 volts, 50-cycle, single phase. A permanent system of degaussing is fitted and is fed from the 225-volt system.

Fluorescent lighting has been fitted in the messes, offices, workshops, galleys and bathrooms. Lighting in the Royal and State apartments is generally by wall bracket and ceiling fittings, although in the dining-room some concealed strip lighting has been used. Arrangements are made for flood-lighting the ship and for the customary outline illumination. The Britannia is the first service ship to be fitted with electric-battery emergency navigational lanterns instead of oil-burning emergency lights.

SEA TRIALS

During the measured-mile speed trials on the Arran course, a full speed of 22·85 knots was obtained with the ship at 4,320 tons displacement and the machinery developing 12,400 s.h.p. at 289 r.p.m. The propulsive coefficient, related to the naked hull effective horse-power deduced from the model results at full speed, was 0·6. There was a moderate sea, and the wind speeds at times reached 50 knots. The wind was more or less on the beam and caused the ship to heel to leeward a few degrees; during a particularly heavy gust the heel reached 10 deg. A rudder angle of about 4 deg. was necessary to maintain a steady course in the most adverse conditions.

Fuel consumption was measured during trials of four hours' duration, each at a steady horse-power. After making adjustments for the maximum seagoing auxiliary load likely to be met on service, the fuel consumption is estimated to be about 47 tons per day at 2,800 s.h.p. and 117 tons per day at 12,000 s.h.p.

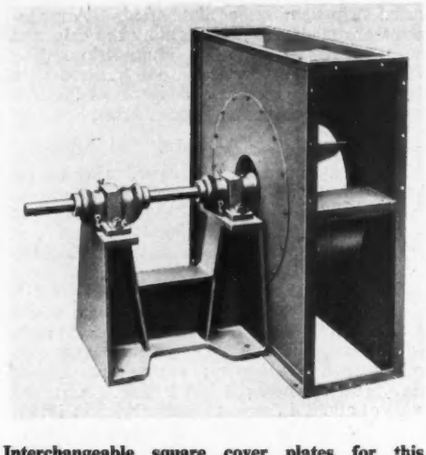
In the load condition, carrying 330 tons of oil fuel, the endurance will be about 2,100 miles at 20 knots and 2,400 miles at the economical speed of 15 knots, with clean bottom. Using the extra fuel tank capacity available for long ocean passages, and carrying 490 tons of oil fuel, the endurance is increased to approximately 3,100 miles at 20 knots and 3,560 miles at 15 knots.

Careful records were taken of any measurable vibration over a wide range of steady speed and also during monoeuvring. Generally, vibration was very small. Maximum vibration was recorded on the upper deck at the extreme stern during full-power trials, when the double amplitude of vertical vibration was at times 0·014 in. and of transverse vibration 0·006 in. The frequency was four times the shaft speed and consistent, therefore, with excitation from the propeller blades. Very occasional transitory vibration of the stern was also noted during full-power trials at comparatively low frequency, not consistent with the shaft speed or the propeller-blade beats. This may have been excited by blows from the sea, as the frequencies were commensurate with the estimated natural hull frequencies. Very small local vibration has noted in a few positions and additional stiffening has been added as considered necessary.

Objectionable singing, which was traced to one propeller only, was experienced during sea trials. In consequence, the spare propellers were shipped after having been modified at short notice by carefully machining the backs of the blades to finer edges. Considerable improvement resulted, but a note was still detected at a low speed. There was also a note at slightly higher speed, but this was eliminated by a small differential adjustment of propeller revolutions between the two shafts. The propellers now fitted have been accepted as an interim measure because the singing is at speeds lower than any likely to be used on passage. Modifications to the original propellers will be made with a view to the complete elimination of singing.

Manœuvring and turning trials verified the ready response of the ship to the rudder. The tactical diameter at 21¼ knots approach speed was 625 yards, i.e., five lengths, and the average rate of turn was slightly more than 1¼ deg. per second.

No really rough weather had been experienced by the ship at the time of preparing this paper, but the behaviour in the moderate sea and strong winds met on the sea trials was in all respects satisfactory and the ship was completely dry, apart from occasional spray. Forced rolling trials were carried out to test the Denny-Brown stabilisers. The ship was rolled through a maximum angle of 30¾ deg. out to out at 21¼ knots ship speed, with the fins operating at an angle of 19¼ deg. each way.



Interchangeable square cover plates for this paddle-blade centrifugal fan enable the direction of rotation and the angle of discharge to be changed easily after installation.

FAN WITH ALTERNATIVE DISCHARGE ANGLES

Use of Interchangeable Cover Plates

A range of V-rope driven centrifugal paddle-blade fans, in which the direction of rotation of the impeller and the angle of discharge can be altered on site to suit changed conditions, has been developed by Matthews and Yates, Limited, Cyclone Works, Swinton, Manchester.

In these fans, an example of which is shown in the accompanying illustration, the cover-plates are interchangeable so that they can be changed over to the opposite sides of the fan casing to permit left- or right-hand rotations.

The fan illustrated is for heavy duties and comprises five components – a cast-iron bearing stool with ball or roller bearings carrying the impeller shaft, a separate drive-side cover plate, the paddle-blade impeller, the square-faced fan casing, and the inlet cover plate. In a lighter-duty version of the fan, the drive-side cover plate incorporates the bearing housing and shaft, but is otherwise similar to that shown.

Each of the frame-side members is an angle section drilled with identical foundation holes so that whichever side is set on the floor becomes the fan base. To alter the direction of the discharge, the drive-side cover plate is first removed and allowed to hang on the shaft. The fan casing is pulled away from the bearing-stool assembly until it clears the impeller. The casing is then rolled over through 90 deg. either way or through 180 deg. to give the desired outlet position. If the direction of rotation is to be altered, the inlet cover plate is removed and the casing is turned on its base through 180 deg. The casing is then pushed back up to the bearing-stool assembly and the cover plates are bolted on.

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LARGE CREEP-RESISTING STEEL FORGING

William Jessop & Sons Ltd., Brightside Works, Sheffield, have produced a large forging of creep-resisting steel. This is a shaft some 8 tons in weight, 14 ft. in length and 35 in. in maximum diameter; it is to be used as the rotor of a large Continental gas-turbine generating plant. The material is a ferritic steel, containing about 12 per cent. of chromium and other additions, which has been used extensively for the rotor discs of the latest gas-turbine engines for British aircraft.

DUPLEX GRINDING MACHINE

Annular Components Ground on Both Sides Simultaneously

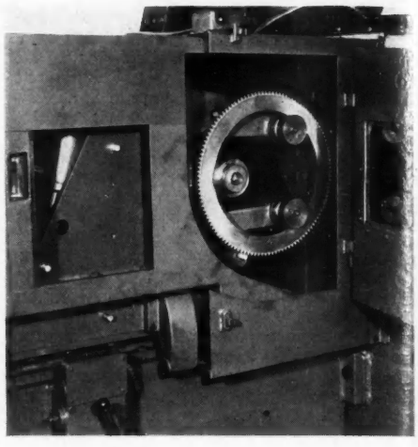
A duplex surface-grinding machine, designed to grind simultaneously the flat annular surfaces on both sides of such components as spur gear rings and clutch discs, has been developed by F. E. Rowland and Company, Limited, Climax Works, Reddish, Near Stockport, Cheshire. A version of this machine, specially made for grinding the faces of sintered-bronze clutch discs, up to 18 in. in diameter, has been installed on the premises of the Morgan Crucible Company, Limited, Battersea Church-road, London, S.W.11. The machine operates on an automatic cycle and is capable, the makers claim, of passing in one hour sixty 18-in. diameter discs, ground to limits of parallelism between 0·001 in. and 0·002 in. The stock removed from such a disc in two passes is 0·034 in. in total depth.

The machine, shown below, is of steel box-construction and is L-shaped in plan. It incorporates cast-iron slideways of large cross-section with narrow guides to ensure rigid and accurate location of the grinding wheels.

The grinding wheel-heads are mounted on the slideways and may be adjusted in two planes. The grinding faces are secured to heavy steel back-plates carried on spindles which run in roller bearings at the driving end and at the other in pre-loaded annular-contact ball bearings. Expansion due to rises in temperature does not influence the accuracy of grinding.

THREE-ROLLER CLAMP

Fitted to the front of the main bed is an extension of fabricated steel, on which is mounted the work-fixture slide. The slide is hydraulically operated and has limits of travel determined by adjustable stops. The work-fixture consists of three rollers, which contact the inside periphery of the clutch disc or other component; one of the rollers acts as driver and the others are idle. Means are provided to vary the relative positions



The work-piece is both clamped and rotated hydraulically with the aid of the rollers shown in this close-up view.

of the rollers in order to accommodate annular discs of different sizes. The manner in which the discs are held is shown above.

The work is clamped in position by means of a hydraulic cylinder which applies a load to the lower front roller; the action of the cylinder is controlled by a lever, which can be seen on the base of the extension. The work is rotated by a hydraulic variable-speed drive and reduction gear, and the machine is capable of a wide range of speeds to suit different work diameters.

The work-fixture is entirely enclosed by a sheet-metal guard and a door is provided to permit loading and unloading. An automatic mechanism prevents the cycle of operations from taking place unless the door is closed.

PRE-SET FEED AND DWELL

At the beginning of the operating cycle, with the wheel-heads in the fully apart position, the disc is loaded on the fixture. It is clamped in position by means of the control lever on the extension base and the loading door is closed.

Both sides of annular components can be ground by this duplex surface-grinding machine. The infinitely-variable axial feed of the grinding wheel-heads and the speed of rotation of the work may be set in advance.

The pressing of a push button sets the machine in motion and, as the work-carriage moves into the grinding position, the work starts to rotate. Immediately the carriage ceases to advance, the wheelheads move inwards at a feed rate predetermined by means of a dial control, which gives a stepless range of speeds. Both heads approach the work simultaneously until they reach a stop position.

The wheel-heads remain there for a dwell period and then move apart until they again reach the outer stops. At the same time the work-carriage returns to the loading point and the work ceases to rotate so that it may be unloaded. The dwell period may be set to any length of time between 5 seconds and 30 seconds by an electrically-operated process timer incorporated in the control panel.

The actions of the wheel-heads and clamping system and the advancing and rotation of the work are all hydraulically operated with the aid of a valve control-gear; and power is supplied by a motor-driven pump unit. A separate motor of 25 h.p. drives the grinding wheels through multiple V-belts. Also hydraulically operated is a grinding wheel dresser located at the rear of the machine. In addition, hydraulic wheel-compensation equipment can be fitted, by means of which the wheelheads may be advanced at independent pre-set feeds to allow for wear of the grinding surfaces and to enable the thickness of the finished component to be controlled.

OTHER SPECIAL-PURPOSE GRINDERS

The machine installed for the Morgan Crucible Company is used to grind clutch discs for heavy caterpillar-type vehicles. These discs consist of sintered-bronze rings fixed to both sides of steel plates. The discs are not rigid and the sintered bronze is very easily removed. The model described here was therefore designed as a special-purpose machine; other versions, however, operating on the same principle, are made, and their applications include the grinding of coil springs, ceramics and turbine blades.

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DERAILMENT OF AN EXPRESS TRAIN: ERRATUM

In our article last week, on page 515, "Derailment of an Express Train," based on the official report of the accident at Wilnecote last August, we quoted the report and described the engine as of the "Royal Scot" class. It was, in fact, engine No. 45699, a Class 6P type of locomotive.

AIRCRAFT ENGINE STARTER

Metal Rectifier Ensures Economy and Safety

The illustration below shows equipment which has been designed by the Westinghouse Brake and Signal Company, Limited, 82 York-way, King's Cross, London, N.1, to supply power for starting the larger types of aircraft engine and to provide the electricity required before take-off. It is operated from the alternating-current mains and ensures economy in the generation of the necessary direct-current.

The equipment consists of a double-wound three-phase transformer and a three-phase full-wave metal rectifier. Both of these as well as the control apparatus, start and stop push buttons and instruments, are mounted on a truck. This truck, when closed, provides complete protection against the weather. It has been designed for manual operation and runs on four 8 in. by 2 in. cushioned rubber-tured wheels. The control equipment includes a contactor on the alternating-current side of the rectifier, which is supplied through the third pin of an international plug and socket which cannot be disconnected while on load. Overload protection has been provided to ensure that the power supplied to the aircraft does not exceed the rating of the rectifier. This is particularly necessary when the equipment is being used on such aircraft as the Stratocruiser, the requirements of which might otherwise result in overloading. Arrangements have also been made for limiting the open-circuit direct-current voltage to about 28·5 volts and at the same time allowing a high enough voltage to be generated to provide the peak current of 1,500 amperes required when starting the aircraft engine.

The set is connected to the aircraft by a flexible cable, the stowage of which special attention has been paid, owing to the necessity of ensuring a quick take-off once the aircraft engines have been started. A supply can be given to aircraft, which are not fitted with a standard plug and socket, through a duplicate cable, interlocks being provided so that only one circuit can be made alive at any one time.

An advantage of such an all-electric set is that it can be used while the aircraft is being re-fuelled. This is not permitted with the prime-mover type of power unit unless it is stationed at least 50 ft. down wind from the aircraft.

Portable engine starter for aircraft, designed for connection to the mains and equipped with a metal rectifier to supply the necessary direct current.

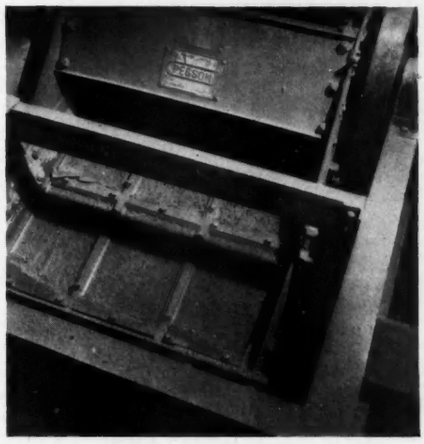

Fig. 1 The screen after electric heating had been switched off for seven or eight minutes, showing the blinding of the meshes by the moist clay.

Fig. 2 A clean mesh showing the advantage gained by electric heating.

VIBRATOR SCREENS HEATED ELECTRICALLY

Clogging Avoided

The ground clay used by Henry Hawkins, Limited, Cannock, for the manufacture of tiles has, until recently, been delivered after grinding to the vibrator screens in a damp condition. As a result, after about ten minutes working, clogging occurred to such a degree that more than 50 per cent. of the fines were returned.

After an attempt had been made to improve conditions by blowing hot air through the screens the problem was solved by passing a large electric current at a low voltage through the meshes and thereby raising their temperature. A supply of electricity for this purpose is obtained from 12-kVA air-cooled single-phase transformers constructed by Woden Transformer Company, Limited, Bilston, Staffordshire. These transformers are totally enclosed against the presence of fine clay dust and are insulated with Class B insulation owing to the difficulty of ventilating them under that condition. They are provided with six tappings so that the current can be varied with the size of the mesh, and the temperature and moisture content of the clay. The advantage gained by heating the screens may be judged by comparing Figs. 1 and 2 above. The installation has been run continuously without supervision since August, 1953, without manual cleaning being necessary.

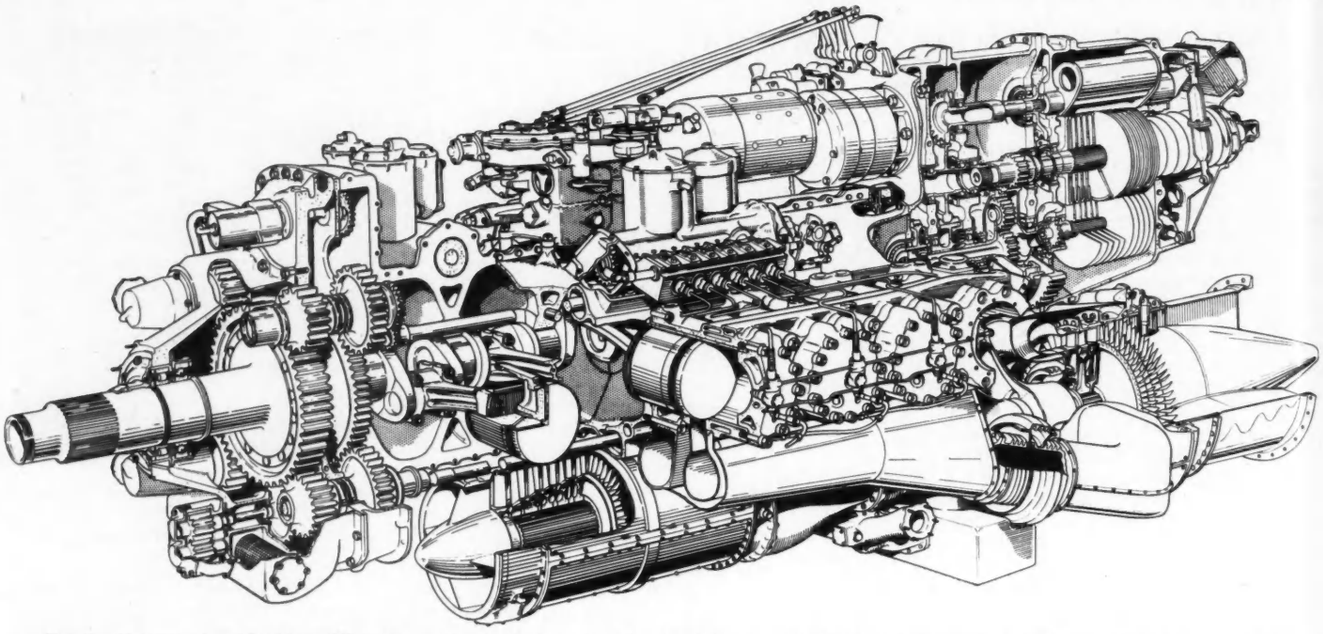

Fig. 1 Cutaway view of "Nomad" engine, a 12-cylinder two-stroke horizontally-opposed Diesel engine compounded with a turbo-compressor unit.

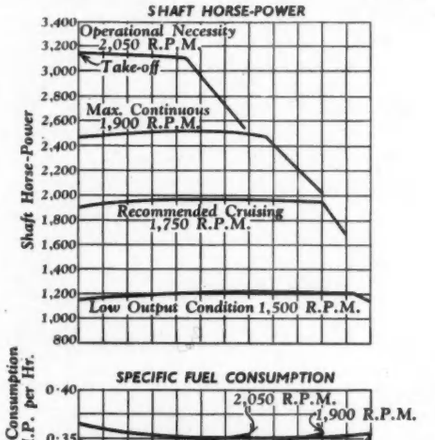

Fig. 2 I.C.A.N. Performance based on shaft horse-power; 300 knots T.A.S.

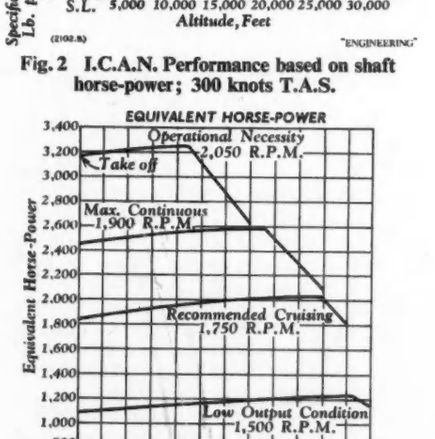

Fig. 3 I.C.A.N. Performance based on equivalent horse-power; 300 knots T.A.S.

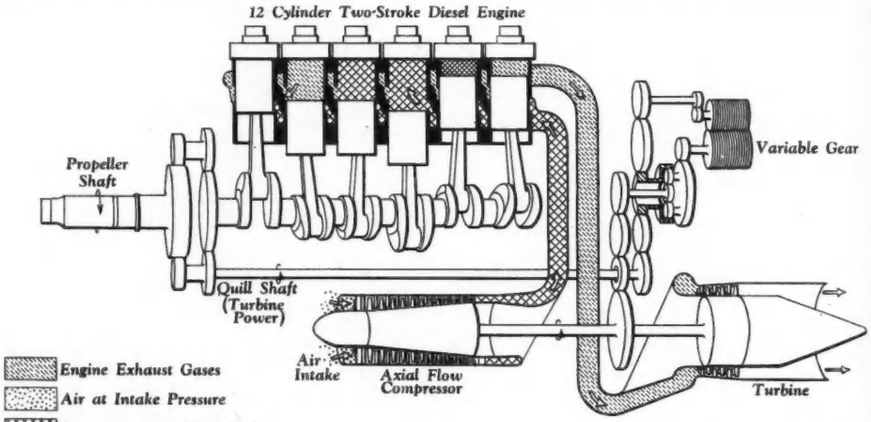

Fig. 4 Diagram illustrating the coupling of the Diesel engine with the turbo-compressor unit.

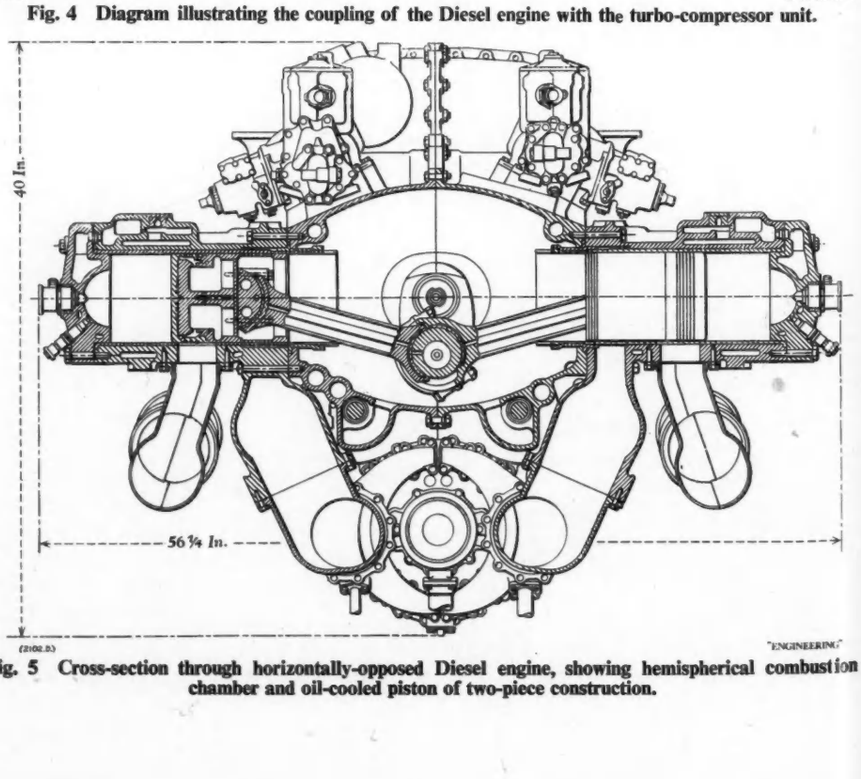

Fig. 5 Cross-section through horizontally-opposed Diesel engine, showing hemispherical combustion chamber and oil-cooled piston of two-piece construction.

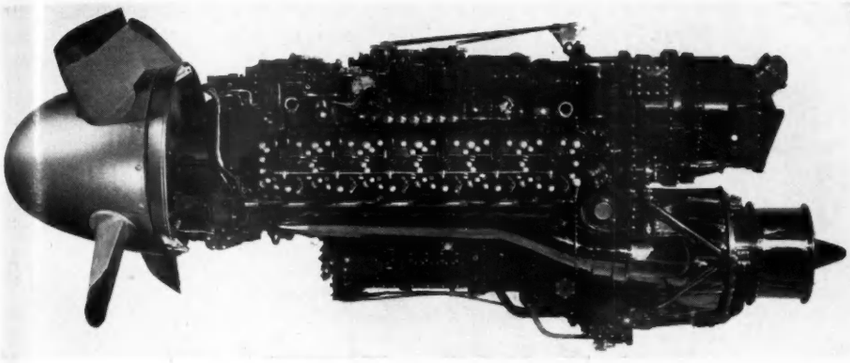

Fig. 6 The "Nomad" compound engine.

"NOMAD" AIRCRAFT ENGINE

TURBO-DIESEL COMPOUND TYPE

Details of the 3,135-h.p. Nomad turbo-Diesel compound aero engine have been released by its constructors, D. Napier and Sons, Limited, Acton, London, W.3. Conceived originally as an economical power plant for civil freight-carrying aircraft, the Nomad is outstanding in its low fuel consumption over a wide range of altitude and operating conditions, and in its ability to use cheap fuels such as Diesel oil. The engine will operate equally well on kerosine or wide-cut gasoline. In the military field, the Nomad is particularly suited for maritime reconnaissance aircraft for which a long duration of flight at low altitudes and speeds is required.

PERFORMANCE

The flexibility and economy of the engine may be appreciated from Table I and from the curves of power and fuel consumption plotted against altitude in Fig. 2, which give the performance related to shaft horse-power, and Fig. 3, related to equivalent horse-power, i.e., taking into account the small amount of jet thrust available. Both sets of curves are for conditions of standard atmosphere at a true air speed of 300 knots.

TABLE I. *Leading Particulars of Nomad Engine*

Performance at sea level:	
Take-off (2,050 r.p.m.)	3,046 s.h.p. at 0·355 lb./s.h.p./hr. 3,135 e.h.p. at 0·345 lb./e.h.p./hr.
Maximum continuous (1,900 r.p.m.)	2,392 s.h.p. at 0·358 lb./s.h.p./hr. 2,448 e.h.p. at 0·350 lb./e.h.p./hr.
Cruising (1,750 r.p.m.)	1,849 s.h.p. at 0·359 lb./s.h.p./hr. 1,893 e.h.p. at 0·351 lb./e.h.p./hr.
Performance at altitude (I.C.A.N. atmosphere 300 knots T.A.S.):	
Operational necessity at 11,000 ft. (2,050 r.p.m.)	3,110 s.h.p. at 0·346 lb./s.h.p./hr. 3,250 e.h.p. at 0·333 lb./e.h.p./hr.
Maximum continuous at 19,000 ft. (1,900 r.p.m.)	2,480 s.h.p. at 0·346 lb./s.h.p./hr. 2,584 e.h.p. at 0·332 lb./e.h.p./nr.
Cruising at 25,000 ft. (1,750 r.p.m.)	1,952 s.h.p. at 0·340 lb./s.h.p./hr. 2,024 e.h.p. at 0·327 lb./e.h.p./hr.
Net dry weight	3,580 lb.

The exceptionally low fuel consumption of the Nomad engine is a direct result of the use of a compound cycle which enables much higher overall compression and expansion ratios to be employed than are possible with either petrol engines or gas-turbine engines, as was discussed recently in a lecture by the company's chief engineer (piston-engine division), a summary of which is given elsewhere in this issue. The compound cycle also has the advantage of rendering the engine insensitive to changes in ambient temperature; it loses less than 2 per cent. take-off power for each 10 deg. C. temperature rise.

Under take-off conditions at sea level, the effective overall compression ratio is 31·5 : 1 and the overall expansion ratio is 24 : 1, the boost pressure being 89 lb. per square inch (absolute) and the brake mean-effective pressure being 205 lb. per square inch. The take-off power is 3,135 effective horse-power, or 76 h.p. per litre, corresponding to a specific weight of 1·17 lb. per horse-power. The specific fuel consumption is 0·345 lb. per effective h.p. per hour.

With increasing altitude up to rated height, the overall expansion ratio of the cycle increases correspondingly, leading to an improvement in specific fuel consumption. As a typical example, at the recommended cruising rating a figure of 0·327 lb. per effective horse-power per hour is obtained at 25,000 ft., the sea-level figure being 0·351 lb. per effective horse-power per hour.

By using water injection into the engine manifolds, the take-off power of the engine is increased to 3,580 effective horse-power corresponding to 87·2 h.p. per litre and a specific weight of 1 lb. per horse-power.

Still further increases in take-off power can be obtained by burning a small quantity of additional fuel in the exhaust manifold between the engine and the turbine, there being sufficient excess air in the exhaust gases for this to be a practical proposition. By a combination of water injection and auxiliary combustion, the take-off power can be increased to 4,095 effective horse-power, corresponding to 99·6 h.p. per litre, the specific weight being reduced to 0·93 lb. per horse-power.

DIESEL ENGINE COUPLED TO TURBO-COMPRESSOR SET

A cutaway view of the Nomad engine is given in Fig. 1, and an external view can be seen in Fig. 6. The mechanical layout is shown in diagrammatic form in Fig. 4, from which it will be seen that the two main components, the Diesel engine and the turbo-compressor set mounted below it, are connected by a gear train incorporating an infinitely-variable gear, which enables the selected boost to be maintained over a wide range of altitudes. The turbine, driven by the Diesel-engine exhaust, is directly coupled to the compressor which supercharges the air supply to the Diesel engine.

The Diesel engine is a 12-cylinder horizontally-opposed unit operating on the two-stroke cycle, the cylinder bore and stroke being 6 in. and $7\frac{3}{8}$ in. respectively, giving a total displacement of 41·1 litres.

The crankcase is of magnesium-zirconium alloy and is split on its vertical centre-line to permit assembly of the six-throw nitrided-steel crankshaft, which is carried in thin-wall bearings of the lead-bronze type.

The two cylinder blocks are aluminium-alloy castings and contain water-jackets for cylinder cooling. The dry cylinder liners, which are of copper-chromium alloy, contain the inlet and exhaust ports which are piston-controlled, there being no valve gear of any kind. The scavenging system gives a well-defined air movement within the cylinder and combines effective scavenging of burned gases from the cylinder with minimum pressure losses.

The combustion chamber is formed in the cylinder head and is hemispherical in shape. It has a centrally situated fuel injector with a central spray orifice and five equally spaced radial orifices – the radial sprays being directed at the combustion-chamber walls.

The injection pumps are mounted in two blocks of six elements, on the port and starboard flange positions on top of the crankcase. They are of "jerk-type" design, specially developed for operating at high speeds and specific outputs.

TWO-PIECE OIL-COOLED PISTONS

The pistons, as may be seen in the cross-sectional view in Fig. 5, are of two-piece construction, comprising a Y-alloy body with an upper portion in austenitic steel, which permits temperatures of over 600 deg. C. at the centre of the crown at full power. Cooling oil, pressure-fed from the crankshaft system through holes drilled in the connecting rod, is directed particularly at the region behind the piston gas rings to ensure that the ring temperature is reduced to a satisfactory working level.

Advantage has been taken of the substantially uni-directional loading on all connecting rods, which result from operating on a two-stroke cycle, to use unconventional forms of big-end and small-end bearings, as shown in Fig. 7. It will be seen that both bearings are of the half-bearing or slipper type, with straps fitted as

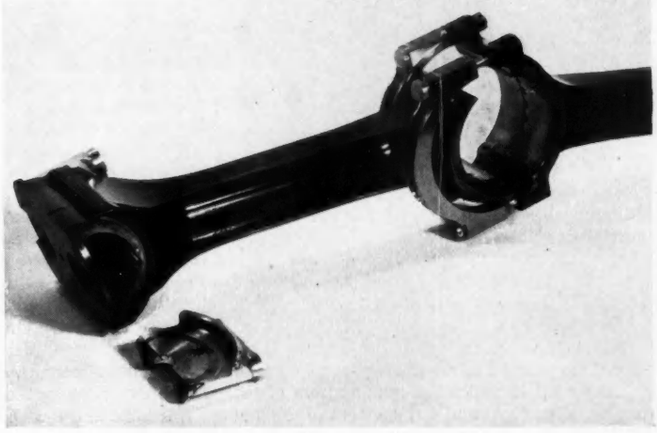

Fig. 7 The big-end and small-end bearings of the connecting rods are of the half-bearing or slipper type.

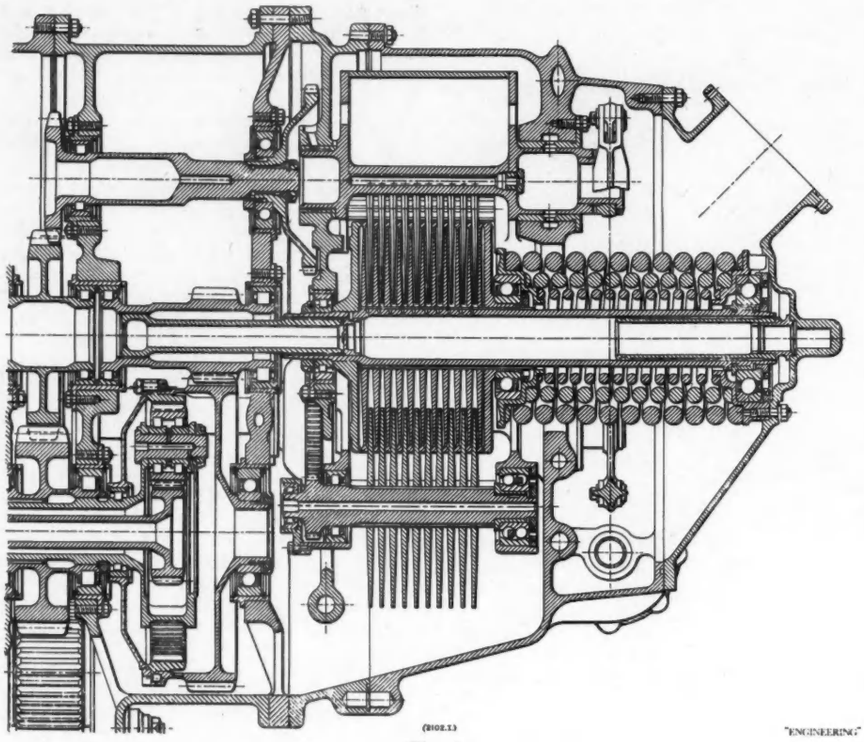

Fig. 9

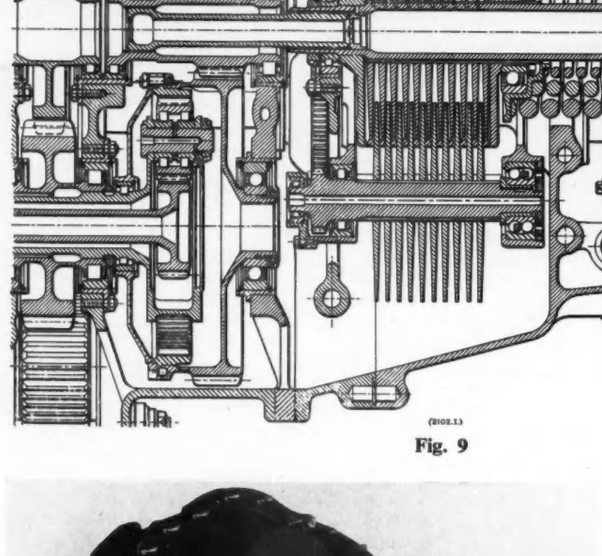

Fig. 8 Arrangement of the epicyclic reduction gear train and the infinitely-variable gear coupling between the turbo-compressor shaft and the propeller shaft. The infinitely-variable gear, shown in Fig. 9, is of the Beier conical-disc type.

safety devices to deal with the light loads in the reverse loading direction.

12-STAGE COMPRESSOR AND THREE-STAGE TURBINE

The axial-flow compressor is suspended by four flexible links below the crankcase, and its entry is arranged to take advantage of " ram " air.

It has 12 stages and a maximum pressure ratio of 8·25 to 1 with an air mass flow of 13 lb. per second. Automatically controlled adjustable inlet guide vanes are employed to extend the operating range of the compressor at low speeds to match the requirements of the turbine. The rotor and stator blades of the first five stages are steel, the remaining stages being of aluminium-bronze.

The turbine, which is mounted co-axially with the compressor, has three stages and is designed to extract the maximum energy from the gases; thus there is only a small residual thrust. The turbine assembly is attached to the rear gear-casing of the engine by a tubular framework. Both the turbine and compressor are connected into this casing by shafts having expansion couplings at each end.

The rear gear casing is machined from a magnesium-zirconium casting and contains the main portion of the reduction gear train between the turbine and the Diesel engine. In addition, it houses the oil sump, the oil pressure and scavenge pumps, and the coolant pumps, and also contains drives for the engine starter and auxiliary gearbox.

INFINITELY-VARIABLE GEAR

The infinitely-variable gear is contained in a housing which is attached to the rear face of the rear gear casing above the turbine. This gear has been designed and developed by the Napier Company to suit the particular requirements of the Nomad application, but the basic scheme was evolved by Dr. Josef Beier and developed in Germany before the second World War. It is an ingenious practical adaptation of the well-known scheme in which two conical members are end-loaded together, the gear ratio being varied by sliding one cone over the other.

Details of the variable gear are shown in Fig. 9. A " pack " of discs with narrow conical rims are arranged on a central shaft and are spring-loaded to trap a series of coned discs carried on three planetary shafts disposed around the central shaft. Each planetary shaft swings around a fulcrum to obtain changes in gear ratio; by attaching a gear to the planetary shaft meshing with one at the fulcrum, it is possible to arrange a constant-mesh gear system so that changes in gear ratio can be made while running.

In operation, the gear is lubricated by high-pressure oil directed at the contact points between each flanged and coned disc. This prevents metallic contact between them – the power being transmitted through the drag force obtained by fluid shear of the oil film.

To reduce the dimensions and weight of the variable gear to a minimum, it is connected into the gear system of the Nomad as indicated in Fig. 8. Here, the speed-reducing gear between the turbo-compressor set and the propeller shaft is of epicyclic form, the variable-speed gear being connected across two members of the epicyclic train. This, in effect, produces two mechanical systems in parallel, only about 30 per cent. of the total power being transmitted through that part of the system in which the speed-varying device is fitted.

ENGINE CONTROLS

The engine is fitted with a single lever control system which relates the speed, boost, and fuel functions together to ensure that a pre-determined power/r.p.m. curve is followed. The speed control is provided by a mechanically-set constant-speed unit varying the propeller pitch. For each speed selected there is a fixed value for boost pressure and for fuel flow. The boost pressure obtained is applied to a normal type of variable-datum boost-control unit, the servo piston of which is connected by a linkage with the control setting of the variable gear. By this means the gear ratio is automatically adjusted to speed up the compressor to maintain the selected boost pressure with increasing altitude until the maximum permitted r.p.m. of the turbo-compressor set is reached. This corresponds to the maximum-power altitude for that particular engine condition and above this point the fuel flow is reduced automatically to correspond with the falling boost.

Thus the engine is capable of maintaining a substantially constant power over a wide range of altitudes. For example, under cruising conditions the operating range over which these conditions apply extends from sea level up to 25,000 ft. Starting is effected by a 112-volt electric starter, which is geared into the crankshaft system. As the compression ratio of the Diesel engine is only 8 to 1, it is necessary to fit a sparking plug in each cylinder, for use only when starting, energised by a high-energy ignition system of Napier design.

TURBO-DIESEL COMPOUND AERO ENGINES

The possibilities for aircraft propulsion of the Diesel engine compounded with a gas turbine were discussed in a lecture entitled " Compound Diesel Engines for Aircraft," given before the Royal Aeronautical Society in London on Thursday, April 22, by Mr E. E. Chatterton, chief engineer of the Piston Engine Division of D. Napier and Son, Limited.

If a piston engine and a gas turbine were designed together to produce a true compound engine, Mr. Chatterton said, the cycle could be manipulated to exploit the most valuable features of both.

The cycle was shared between a two-stroke Diesel engine and a gas turbine, exhaust gases from the engine being fed to the turbine. The back pressure imposed by the turbine on the engine cylinders established the lower pressure level of the operating cycle in the cylinders, and also determined the degree of supercharge necessary to pass the required quantity of air through the engine. Due to the high degree of compression taking place outside the engine cylinders, and to the fact that expansion in the turbine extended down to atmospheric pressure, a very high overall expansion ratio could be used.

The division of work between the Diesel engine and the turbine, although it did not materially affect the limiting thermal efficiency of the compound cycle, had considerable influence on the dimensions and weight of the combined unit. The cycle could be designed so that the excess air was a relatively high proportion of the total mass flow, thus reducing the exhaust-gas temperature and allowing the turbine inlet pressure to be raised. This adjustment also raised the supercharge pressure, resulting in a higher mean indicated pressure. The thermal loadings in the engine cylinders set the limit to the extent of this adjustment, but the passage of excess air through the cylinders provided a considerable degree of internal cooling.

The three major mechanical elements – the two-stroke Diesel engine, the gas turbine and the compressor – could be mechanically combined in three ways. (1) The compressor could be driven by the turbine, all output power being delivered by the piston engine, in effect a Diesel engine with a turbo-blower. (2) The compressor could be driven by the piston engine, all output power being taken from the turbine, the piston-engine/compressor combination operating solely as a gas generator. (3) All three components could be coupled together to form a common mechanical system.

In the third system alone there was no requirement for power equilibrium between any two components. This allowed the greatest possible flexibility in the choice of operating conditions for best performances over the whole speed range, and resulted in the lightest possible power plant. The compressor and turbine could be connected solidly together, the reduction gearing connecting them into the engine system being called upon to transmit only the difference in power produced by the turbine and that demanded by the compressor.

If an infinitely-variable gear were employed, the power and consumption could be maintained sensibly constant over a wide range of values. Moreover, the gear ratio could be adjusted at any flight condition to take full advantage of air intake " ram," and the compressor could be driven up to its maximum speed at any engine speed, thus permitting greater altitude to be achieved at low engine speeds. This arrangement had been adopted in the Nomad engine, a full description of which will be found elsewhere in this issue.

BARRELLING TO FINE LIMITS

Improvement of Surfaces

A barrelling process capable of consistent control within fine limits of accuracy was demonstrated at their laboratory by Roto-Finish, Limited, 39 Park-street, London, W.1, on Thursday, April 8. The operations performed by the process include radiusing, de-burring, de-scaling, de-flashing, surface improvement, polishing and honing; and economies in time and labour made possible by the process can, it is claimed, be as great as 80 per cent.

Among the materials so far successfully subjected to " rotofinishing " are 95-ton tensile steels, components of which were radiused and de-burred in nine hours, aluminium alloys, zinc-based alloys in the form of die-castings, brasses, phosphor-bronze and cyanide surface-hardened steels. Matt or bright finishes can be obtained, depending on the barrelling medium and auxiliary compound used, and in the case of steel forgings, for example, surface quality can be improved in 8 to 10 hours from a surface-roughness range of 30 micro-inches to one of 7 micro-inches.

ROLLING AND ABRASIVE PROCESS

The process, which is of American origin, is the direct outcome of earlier tumbling techniques and involves a rolling and abrasive rather than a peening action. This serves to close the pores of the material without introducing foreign inclusions into its surface, thus largely eliminating irregularities of composition and the danger, in certain cases, of electrolytic corrosion.

The equipment consists of a rubber-cushioned octagonal cylinder which slowly rotates and causes a circulating action of processing chips. If the components are small they are introduced separately into the cylinder – together with an appropriate processing compound in solution – and allowed to circulate freely among the chips. A calculation of the limiting ratio of chips to components can be made so that no component impinges upon another. The nature of the processing compound depends upon the operation to be performed and the character of the metal to be treated. Larger items are secured to fixtures within the cylinders.

The type DW 30-36-1 rotofinishing machine includes a stationary fixture which can carry such articles as turbine rotors. By releasing hand-clamps, one of the faces of the octagonal cylinder can be removed. A trolley beneath the cylinder collects the chips on completion of the process after washing and draining.

PROCESS CONTROL

The action is such that adequate contact pressure and motion are maintained between the part to be processed and the abrasive or polishing particles. The mass of chips – and components if they are loose – is carried round by the cylinder in a position of repose until the point is reached where the chips begin to slide under gravity; this movement provides a continuously sliding top layer through which the components pass. By varying the type or packing of processing chips, the compound, or the speed of circulation, results ranging from harsh cutting to fine polishing can be obtained.

In order that an appropriate combination of these factors be determined for a given duty, analyses of components are performed at the Roto-Finish Laboratory before plant is installed, so that suitable operating conditions can be recommended in every case.

Although the standard rate of rotation of the barrel is 20 r.p.m., variable-speed drives can be fitted to give a range of speeds from 10 r.p.m. to 30 r.p.m. These are of particular value for processing components over 1½ lb. in weight or extremely delicate parts. Higher speeds give a harsh action and may be used when dimensional losses are unimportant. High surface finishes on large components can be achieved at slower speeds.

PROCESS-TIMING AND DISCHARGE

Not only is the rate of rotation controlled but also its duration; a process-timer is included in the starter circuit and enables the machine to be operated without supervision. Accurate control of the barrel is obtained by means of an inching button which is linked with a magnetic brake and simplifies loading and unloading. Doors are secured by spring-loaded quick-acting cam-locks. A perforated wash-out door is fitted so that chips or parts are not lost when dirt and compound solutions are flushed from the barrel.

In the illustration below is shown the model DW 16-16-2 " Midget " machine. This version, as indicated in its classification, has a barrel 16 in. wide and 16 in. between faces of the octagonal drum, and is divided into two 8-in. compartments. It is used for small components and, since these move freely among the chips, it incorporates a screening pan, which can be seen in the lower part of the machine. When the operation is completed, the charge is washed and tipped into this pan which is shaken and the components thereby separated from the chips.

Seventeen chip sizes are employed in the process ranging approximately from 1¾ in. to $\frac{1}{16}$ in. in diameter. Two principal types of chip, the grinding chip and the " britehoning " chip, are used, and, in addition, special coruloy chips are made synthetically for rapid operation. Among the auxiliary compounds, which are added, are those designed to lubricate the chips or add to their abrasive quality, but all compounds are intended to prevent tarnishing, etching or rusting of the components and to maintain the cleanliness of the chip mass.

In cases where the components to be processed include sections already machined to fine limits, they may be protected where necessary by masking with plastic material. In this way, parts as delicate as those employed in watch-making may be treated. Various other models are available for different purposes.

Parts as delicate as watch components and as hard as cyanide-treated steels may be de-burred, radiused and polished by this barrelling machine.

FORTHCOMING EXHIBITIONS AND CONFERENCES

This list appears in the last issue of each month. Organisers are invited to send to the Editor particulars of forthcoming events.

FOURTH INTERNATIONAL PAPER, PRINTING AND ALLIED TRADES EXHIBITION. Sat., May 1, to Wed., May 12, at the Grand Palais, Champs Elysées, Paris. Organised by the Salon des Techniques Papetières et Graphiques, 40 Rue du Colisée, Paris, 8e.

INTERNATIONAL CONFERENCE ON OIL AND COAL GASIFICATION. Mon., May 3, to Sat., May 8, at Liége. Organised by the Institut National de l'Industrie Charbonnière, 7 Boulevard Frère Orban, Liége, Belgium. See also our issue of April 16, page 501.

BRITISH INDUSTRIES FAIR. Mon., May 3, to Fri., May 14, at Earl's Court, London, S.W.5 ; Olympia, London, W.14 ; and Castle Bromwich, Birmingham. Particulars obtainable from the director, British Industries Fair, Board of Trade, Lacon House, Theobald's-road, London, W.C.1. Tel. CHAncery 4411 ; or from the general manager, British Industries Fair, 95 New-street, Birmingham, 2. Tel. Midland 5021.

EXHIBITION OF ARCHITECTURE AND BUILDING, AUSTRALIA. Mon., May 3, to Fri., May 28, at Sydney. Held in conjunction with the 1954 Australian Architectural Convention. Organised by the Royal Australian Institute of Architects, 16 Barrack-street, Sydney.

PHOTOGRAPHIC AND CINE EXHIBITION. Tues., May 4, to Sat., May 15, at Manchester. Organised by Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester. Tel. Deansgate 6363.

OXIDATION PROCESSES CONFERENCE. Thurs., May 6, to Sat., May 8, at Amsterdam. Apply to the secretary of the organising committee, Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. Tel. VICtoria 6161. See also our issue of February 26, page 271.

SYMPOSIUM ON MIX DESIGN AND QUALITY CONTROL OF CONCRETE. Tues., Wed. and Thurs., May 11, 12 and 13, at the Institution of Civil Engineers, Great George-street, London, S.W.1. Further particulars obtainable from the secretary, the Cement and Concrete Association, 52 Grosvenor-gardens, London, S.W.1. Tel. SLOane 5255. Alteration of dates. See also our issue of July 24, 1953, page 108.

INTERNATIONAL HIGH TENSION CONFERENCE. Wed., May 12, to Sat., May 22, at 28 Rue Saint Dominique, Paris. Organised by the Conférence Internationale des Grands Réseaux Electriques, 112 Boulevard Haussmann, Paris. Apply to the secretary, C.I.G.R.E. British National Committee, Thorncroft Manor, Dorking-road, Leatherhead, Surrey. Tel. Leatherhead 3423. See also our issue of January 8, page 62.

PAPER AND PRINTING INTERNATIONAL FAIR. Sat., May 15, to Sun., May 30, at Dusseldorf. *Agents:* John E. Buck & Co., 47 Brewer-street, London, W.1. Tel. GERrard 7576.

FOURTH GAUGE AND TOOL EXHIBITION. Mon., May 17, to Fri., May 28, in the New Hall of the Royal Horticultural Society, Greycoat-street, Westminster, London, S.W.1. Organised by the Gauge and Tool Makers' Association, Standbrook House, Old Bond-street, London, W.1. Tel. HYDe Park 3451.

INTERNATIONAL RAILWAY CONGRESS. Wed., May 19, to Wed., May 26, in London. Applications to Mr. J. Dumont, International Railway Congress Association, 19 Rue du Beau Site, Brussels.

NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING, OPEN DAYS. Wed. and Thurs., May 26 and 27, at Wrest Park, Silsoe, Bedfordshire. See also our issue of February 19, page 243.

SCOTTISH INDUSTRIAL DESIGN CONGRESS AND EXHIBITION. Wed. and Thurs., May 26 and 27, at Edinburgh. Organised by the Council of Industrial Design Scottish Committee, 95 Bothwell-street, Glasgow, C.2. Tel. Central 2991. See also our issue of March 19, page 360.

CANADIAN INTERNATIONAL TRADE FAIR. Mon., May 31, to Fri., June 11, at Toronto. Apply to Miss M. A. Armstrong, Canadian Government Exhibition Commission, Canada House, Trafalgar-square, London, S.W.1. Tel. WHItehall 8701.

MELBOURNE ENGINEERING EXHIBITION. Mon., May 31, to Sat., June 5. Apply to the director, Industrial Public Relations Bureau of Australia, 259 Collins-street, Melbourne, Australia.

IRON AND STEEL INSTITUTE MEETING. Mon., June 7, to Fri., June 18, in Sweden. Apply to the Iron and Steel Institute, 4 Grosvenor-gardens, London, S.W.1. Tel. SLOane 0061. See also our issue of March 12, page 325.

FOURTH MECHANICAL HANDLING EXHIBITION. Wed., June 9, to Sat., June 19, at Olympia, London, W.14. Organised by *Mechanical Handling*, Dorset House, Stamford-street, London, S.E.1. Tel. WATerloo 3333.

CONFERENCE ON CIVIL ENGINEERING PROBLEMS IN THE COLONIES. Mon., June 14, to Fri., June 18, at the Institution of Civil Engineers, Great George-street, London, S.W.1. Apply to the secretary of the Institution at that address. Tel. WHItehall 4577. See also our issue of July 17, 1953, page 87.

SIXTH BRITISH ELECTRICAL POWER CONVENTION. Mon., June 14, to Fri., June 18, at Eastbourne. Organised by the British Electrical Development Association, 2 Savoy-hill, London, W.C.2. Tel. TEMple Bar 9434. See also our issue of January 15, page 71.

BUILDING PLANT EXHIBITION. Thurs., June 24, to Wed., June 30, at Hills Meadow, Reading. Organised by the Ministry of Works. Apply to the principal information officer, Room 117, Lambeth Bridge House, London, S.E.1. Tel. RELiance 7611.

SYDNEY ENGINEERING EXHIBITION. Mon., July 5, to Sat., July 10. Apply to the offices of the exhibition, 66 Bathurst-street, Sydney, Australia.

ROYAL SHOW. Tues., July 6, to Fri., July 9, at Windsor. Organised by the Royal Agricultural Society of England, 16 Bedford-square, London, W.C.1. Tel. MUSeum 5905.

"PRODUCTION FOR PLENTY" EXHIBITION AND CONFERENCE. Wed., July 7, to Wed., July 14, at Olympia, London, W.14. Organised by the Institution of Production Engineers, 36 Portman-square, London, W.1. Tel. WELbeck 6813. See also our issue of February 12, page 194.

NON-DESTRUCTIVE TESTING CONFERENCE. Wed., July 7, to Sat., July 10, at the Chancellor's Hall, University of Birmingham. Organised by the Non-Destructive Testing Group, Institute of Physics, 47 Belgrave-square, London, S.W.1. Tel. SLOane 9806. See also our issue of April 23, page 515.

INDUSTRIAL ELECTRONICS CONVENTION. Thurs., July 8, to Mon., July 12, at Christ Church, University of Oxford. Organised by the British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. Tel. MUSeum 1901. See also our issue of Mar. 26, page 413.

LAUNDRY, DRY CLEANING AND ALLIED TRADES EXHIBITION. Thurs., July 8, to Sat., July 17, at Olympia, London, W.14. Organisers: F. W. Bridges and Sons, Ltd., Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 0568.

GREAT YORKSHIRE AGRICULTURAL SHOW. Tues., July 13, to Thurs., July 15, at Harrogate. Organised by the Yorkshire Agricultural Society, Great Yorkshire Showyard, Hookstone-drive, Harrogate. Tel. Harrogate 6014.

CONFERENCE ON DEFECTS IN CRYSTALLINE SOLIDS. Tues., July 13, to Sat., July 17, at the H. H. Wills Physical Laboratory, Royal Fort, Bristol, 8. Organised in conjunction with the Institute of Physics. Further particulars may be obtained from the secretary of the Laboratory; or the secretary, Institute of Physics, 47 Belgrave-square, London, S.W.1. Tel. SLOane 9806.

RADIOISOTOPE CONFERENCE.—Mon., July 19, to Sat., July 24, at Oxford. Arranged by the Atomic Energy Research Establishment, Harwell. Further details obtainable from the conference secretary, A.E.R.E., Harwell, Didcot, Berkshire. Tel. Abingdon 620.

WORLD POWER CONFERENCE, SECTIONAL MEETING. Sun., July 25, to Tues., Aug. 10, at Rio de Janeiro, Brazil. Applications should be sent to the secretary, British National Committee, World Power Conference, 201-2 Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 3966.

HARROGATE: THE RIDINGS INTERNATIONAL FAIR. Sat., July 31, to Sat., Aug. 14. Organised by Regional Exhibitions, Ltd., Salfords, Surrey. Tel. Horley 64.

INTERNATIONAL MODEL ENGINEER EXHIBITION. Wed., Aug. 18, to Sat., Aug. 28, at the New Horticultural Hall, Greycoat-street, London, S.W.1. Apply to Mr. G. Withers, 19 and 20 Noel-street, London, W.1. Tel. GERrard 8811.

21ST NATIONAL RADIO AND TELEVISION EXHIBITION. Wed., Aug. 25, to Sat., Sept. 4, at Earl's Court, London, S.W.5. Apply to the Radio Industry Council, 59 Russell-square, London, W.1. Tel. MUSeum 6901.

FIFTH SYMPOSIUM ON FLAME AND COMBUSTION. Mon., Aug. 30, to Fri., Sept. 3, at the University, Pittsburgh. Apply to the chairman of the organising committee, Dr. B. Lewis, 200 Alcoa Building, Pittsburgh 19, U.S.A.

BRITISH ASSOCIATION MEETING. Wed., Sept. 1, to Wed., Sept. 8, at Oxford. Apply to the secretaries, British Association for the Advancement of Science, Burlington House, Piccadilly, London, W.1. Tel. REGent 2109. See also our issue of April 23, page 518.

SCOTTISH INDUSTRIES EXHIBITION. Thurs., Sept. 2, to Sat., Sept. 18, at the Kelvin Hall, Glasgow. Apply to the offices of the exhibition, 16 Woodside-terrace, Glasgow, C.3. Tel. Douglas 8811.

FLYING DISPLAY AND EXHIBITION, FARNBOROUGH. Mon., Sept. 6, to Sun., Sept. 12, at Farnborough, Hampshire. Open to the public on Fri., Sat. and Sun., Sept. 10, 11 and 12 only. Organised by the Society of British Aircraft Constructors, Ltd., 32 Savile-row, London, W.1. Tel. REGent 5215.

WELSH INDUSTRIES FAIR. Wed., Sept. 8, to Sat., Sept. 18, at Sophia Gardens Pavilion, Cardiff. Organised by the National Industrial Development Council of Wales and Monmouthshire Ltd., 17 Windsor-place, Cardiff. Tel. Cardiff 23049.

WAVE RESEARCH CONGRESS. Wed., Sept. 8, to Sat., Sept. 11, at Grenoble, France. Held under the auspices of the Council on Wave Research of the Engineering Foundation, University of California. Communications to the Coast Engineering Congress, Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique, 44-46 Avenue Félix Viallet, Grenoble, France. See also our issue of April 16, page 500.

WEST COUNTRY INTERNATIONAL FAIR. Sat., Sept. 11, to Sat., Sept. 25, at Bristol. Organised by Regional Exhibitions, Ltd., Salfords, Surrey. Tel. Horley 64.

FIRST INSTRUMENT CONGRESS AND EXPOSITION. Mon., Sept. 13, to Fri., Sept. 24, in the Commercial Museum and Conference Hall, Philadelphia. Sponsored by the Instrument Society of America. Apply to the manager, Mr. Richard Rimbach, 845 Ridge-avenue, Pittsburgh 12, Pennsylvania, U.S.A.

SUSSEX INDUSTRIES FAIR. Wed., Sept. 15, to Sat., Sept. 25, at the Corn Exchange, Brighton. Organised by the Federation of Sussex Industries, Ltd., 32 Duke-street, Brighton 1. Tel. Brighton 26189.

INTERNATIONAL COMMERCIAL MOTOR TRANSPORT EXHIBITION. Fri., Sept. 24, to Sat., Oct. 2, at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders, Ltd., 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

ASLIB ANNUAL CONFERENCE. Fri., Sept. 24, to Mon., Sept. 27, at Church House, London, S.W.1. Further information obtainable from the secretary, Aslib, 4 Palace-gate, London, W.8. Tel. WEStern 6321.

BUSINESS EFFICIENCY EXHIBITION, MANCHESTER. Mon., Sept. 27, to Sat., Oct. 2, at the City Hall, Manchester. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate-hill, London, E.C.4. Tel. CENtral 7771.

ENGINEERING INDUSTRIES ASSOCIATION: LONDON REGIONAL DISPLAY. Tues., Oct. 12, to Thurs., Oct. 14, at the Royal Horticultural Society's New Hall, Greycoat-street, London, S.W.1. Apply to the secretary of the Association, 9 Seymour-street, Portman-square, London, W.1. Tel. WELbeck 2241.

BUILDING TRADES EXHIBITION. Tues., Oct. 19, to Sat., Oct. 30. Apply to Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester, 3. Tel. Deansgate 6363.

BRITISH TRADE FAIR, BAGHDAD. Mon., Oct. 25, to Mon., Nov. 8, at Baghdad, Iraq. Organised, at the invitation of H.M. Government, by British Overseas Fairs, Ltd., 21 Tothill-street, London, S.W.1. Tel. WHItehall 6711. See also our issue of January 29, page 135.

ELECTRICAL AND RADIO EXPOSITION. In October, at Melbourne, Australia. Organised by the Electrical and Radio Federation (Victoria), Dominion Chambers, 59 William-street, Melbourne, C.1.

CYCLE AND MOTOR CYCLE SHOW. Sat., Nov. 13, to Sat., Nov. 20, at Earl's Court, London, S.W.5. Organised by the British Cycle and Motor Cycle Manufacturers' and Traders' Union, Ltd., The Towers, Warwick-road, Coventry. Tel. Coventry 62511.

POWDER METALLURGY SYMPOSIUM AND EXHIBITION. Wed. and Thurs., Dec. 1 and 2, at Church House, Great Smith-street, London, S.W.1. Organised by the Iron and Steel Institute and the Institute of Metals. Apply to the secretary, Iron and Steel Institute, 4 Grosvenor-gardens, London, S.W.1. Tel. SLOane 0061. See also our issue of April 23, page 518.

Labour Notes

YOUNG ENGINEERS IN CONFERENCE

As is usual at general conferences of trade-union representatives, a number of demands for higher wages and better working conditions were put forward at the annual conference of young engineering employees belonging to the Amalgamated Engineering Union, which took place at Eastbourne on April 22 and 23. The meeting was attended by 49 delegates, representing the junior members of the union's 26 divisions.

During a discussion on wages on the first day, strenuous but unsuccessful efforts were made by some of the delegates to get the union's executive council to press immediately for substantial all-round increases in the percentages of skilled rates paid to apprentices. The percentage rates sought for the apprentices were 52½ per cent. of the skilled rate for lads aged 15, 57½ per cent. for those aged 16, 65 per cent. for those aged 17, and 72½ per cent. for those aged 18. It was also urged that lads aged 19 and 20 should receive 80 per cent. and 90 per cent., respectively, of the rate for skilled men.

An amendment expressing profound dissatisfaction at the failure of the union's executive council to secure a previous claim for an increase of 20*s.* a week for the apprentices was rejected.

Mr. Jack Tanner, the union's President, who presided at the conference, told the delegates that pressure for immediate increases for all apprentices would mean scrapping the union's present policy in respect to rises in wages for these youths and replacing it by an entirely new one. The union had to be practical in its negotiations with the employers, who were firmly opposed to the granting of sweeping wage awards.

At the present time, Mr. Tanner stated, the executive council was concentrating on obtaining advances for the older apprentices, aged from 18 to 20 years.

PIECEWORK AND NIGHT SHIFTS

In the end, the debate on apprentices' wages was brought to a close by the passing of a resolution which did no more than urge the union's executive council to press forward with their existing application, but the delegates asked that efforts to obtain the percentage increases desired should be given priority in the union's negotiations.

Turning to suggested improvements in other directions, the delegates passed, by an overwhelming majority, a resolution demanding the abolition of piecework for all classes of apprentices and the substitution of a shop bonus system. This resolution, which did not have the approval of the executive council, was put forward on the ground that piecework for apprentices was detrimental to their efficient training.

There seemed to be a general measure of agreement among the delegates that the working of night shifts by lads of up to 18 years of age was wrong for health reasons, although some delegates considered that apprentices should be permitted to choose for themselves whether or not they would work on night shifts. Eventually, a resolution was passed asking that the executive council should seek to abolish night-shift working for apprentices.

TRAVEL ALLOWANCES AND HOLIDAYS

The delegates decided against asking employers to contribute towards the travelling expenses of young employees. It was felt that such allowances, if granted, might lead to undue preference being given to lads living closest to the employers' works.

Further resolutions, which were also carried, requested a month's annual holiday, in place of ten days, as at present, for lads under 18 years of age, and the granting of full pay during periods of sickness.

Another resolution demanded the fuller implementation of the industry's agreement for the recruitment and training of juveniles, especially in respect to such matters as training, the provision of adequate equipment, and the supply of tools and textbooks.

On the second day, the delegates requested that the Government be asked to ensure that national service men are not used in place of civilian employees in industrial disputes. The conference is advisory only.

HIGHER WAGES FOR WOMEN ENGINEERING EMPLOYEES

Increases in the wage rates of women engaged in the engineering group of industries were agreed to at a meeting in London on April 26 between representatives of the Engineering and Allied Employers' National Federation and the five principal unions representing women operatives.

Women aged 18 and over will receive 5*s.* 8*d.* a week more and there will be rises of 3*s.* 8*d.* a week for girls aged 17 years, 3*s.* 1*d.* a week for girls of 16, and 2*s.* 5*d.* a week for girls of 15. For employees engaged on time work, the increase will be added to their consolidated time rate.

Persons engaged on payment-by-results schemes will have the increase added to the supplements which are paid to them in addition to their piecework earnings. The agreement will bring the minimum wage for women manual employees up to £4 17*s.* 2*d.* for a week of 44 hours. It will come into operation as from Monday, April 5. The unions represented at the negotiations were the Amalgamated Engineering Union, the Electrical Trades Union, the Amalgamated Union of Foundry Workers, the Transport and General Workers' Union, and the National Union of General and Municipal Workers. In all, some 785,000 women will benefit.

CIVIL-ENGINEERING CONSTRUCTORS RECEIVE HIGHER RATES

Navvies, labourers and craftsmen engaged on civil-engineering construction are to be paid an additional 1½*d.* an hour as from May 24, according to the terms of an agreement announced by the Civil Engineering Construction Conciliation Board for Great Britain on April 23.

This increase will raise the minimum rate for navvies and labourers employed in the London area to 3*s.* 5*d.* an hour, and for those engaged in the provinces to 3*s.* 3½*d.* an hour. The minimum rate for craftsmen employed in the London and Liverpool districts will be raised to 3*s.* 10½*d.* an hour, and that for craftsmen working in other parts of the country to 3*s.* 9*d.* an hour.

WAGE INCREASES FOR SHIPBUILDING DRAUGHTSMEN

Negotiations on wage rates for draughtsmen engaged in the shipbuilding and ship-repairing industries took place at a conference between representatives of the Shipbuilding Employers' Federation and officials of the Association of Engineering and Shipbuilding Draughtsmen in London on April 22. The Federation's representatives agreed to recommend to shipbuilding firms affiliated to their organisation that draughtsmen in these industries aged 21 and 22 years should receive an increase of £22 10*s.* a year, those aged 23 and 24 years an advance of £25 a year, and those aged 25 years or over an extra £27 10*s.* a year.

It was also recommended that lady tracers should be paid an increase of 7*s.* a week and that there should be proportionate advances for juveniles. According to a statement issued after the meeting by the A.E.S.D., between three and four thousand members of the Association will be affected by this award, and it is expected that payment of the increases will commence at a very early date.

RAILWAY DISPUTES

A decision to work to rule, which is expected to involve some hundreds of railway employees, is reported to have been taken by the Plymouth Branch of the National Union of Railwaymen on April 23. The men have decided upon this action as a means of protesting against the ruling of the British Transport Commission that all marshalling yards in the Western Region of British Railways shall be closed from 6 a.m. to midnight on Sundays, as an economy measure.

An official of the union suggested that the closure of the yards was a false economy, in that it would result in railway traffic being delayed for periods of at least 24 hours. This was calculated to have a very bad effect on the volume of goods dispatched by the railway service, which was already losing much of its trade to the road-transport industry. The railwaymen, he stated, were concerned not only on that account but also because the Sunday staffs would be deprived of their turns of duty.

Another difficulty has arisen among engineering employees at the Swindon workshops of British Railways, where a meeting of the men on April 23 decided to bring pressure to bear upon the Commission to grant payment for all statutory holidays. In furtherance of this cause, a resolution was passed that the branch committee should seek the support of men engaged at other railway centres in Great Britain. Existing agreements provide that the men shall be paid only for Whit Monday and August Bank Holiday, and not for Good Friday, Easter Monday, Christmas Day and Boxing Day.

UNION'S SUGGESTIONS ON RAILWAY COSTS

Proposals for meeting the steadily mounting cost of operating the railway service are made by Mr. J. S. Campbell, the general secretary of the National Union of Railwaymen, in last Friday's issue of the *Railway Review*, the union's official journal. Mr. Campbell disapproves of further increases in railway passenger fares or freight charges, and suggests, as an alternative, that there should be a Government subsidy.

Such a grant, he contends, is no more than the railways' due, and would be but a form of "restoration or restitution." He reminds his readers that the Government took from the industry the very considerable sum of 124 million pounds during the war, and the subsequent period of control up to 1948, by way of profits which were not made available to the railway companies, although the industry needed capital.

As a recompense for that, Mr. Campbell feels that the Government should now underwrite the difference between the net earnings of British Railways and the total central charges of the service during the next five years. He defines central charges as the cost of central administration, transport stock and other interest charges, redemption funds, and a number of "special items."

The amount required would not approach the 124 million pounds taken by the Government but such a gesture, Mr. Campbell believes, would bring about a period of calm in the industry during which an intensive effort should be made to improve its general efficiency in all departments.

CONTRACTS

Coal-Preparation Plant. An order has been received by the FRASER AND CHALMERS ENGINEERING WORKS of the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, from the National Coal Board, South-Western Division, for a Chance coal-preparation plant for the Onllwyn Group of Collieries in the No. 9 area of the Division. A 10-ft. diameter Chance cone will be capable of dealing with 150 tons per hour of 5 in. by ⅜ in. raw coal. The order includes electrical equipment for pumps, crushers, and conveyors, together with the electrical equipment necessary for the small-coal washery and for the run-of-mine screening plant which is being supplied by the NORTON-HARTY ENGINEERING CO. LTD., Great Bridge, Tipton, Staffordshire. Coal brought to the site by railway transport from several anthracite pits will be cleaned at this central washery.

Continental Train-Ferry Vessel. The Eastern Region of British Railways has received authority from the British Transport Commission to order a new train-ferry vessel for the Harwich-Zeebrugge Continental service, to replace the Essex Ferry built in 1917 and now almost at the end of her useful life. The new ship will be built by JOHN BROWN & CO. LTD., Clydebank, Dumbartonshire, and will cost upwards of £600,000.

Coke-Oven Plant. A battery of 150 twin-flue compound coke ovens, together with by-product plant and coal and coke-handling equipment, are to be built at the Cleveland Iron and Steel-works of Dorman, Long & Co. Ltd., Middlesbrough, by SIMON-CARVES LTD., Cheadle Heath, Stockport. The new plant will carbonise 1,250,000 tons of coal a year to supply coke to two new blast furnaces having a joint annual capacity of 750,000 tons of iron.

Electronic Computer. In order to lighten the heavy burden of routine basic calculation involved in reconciling the physical possibilities of aircraft with the theoretical demands for performance, airworthiness, strength, weight and the stowage of loads and also in connection with vibration, delta-wing and stability calculations, A. V. Roe Ltd. have ordered an electronic computer from FERRANTI LTD., Hollinwood, Lancashire. The computer is scheduled to be installed this autumn and will cost some £100,000.

Hydro-Electric Scheme in Turkey. Negotiations, recently completed in Ankara, between the Government of Turkey and the ENGLISH ELECTRIC CO. LTD. and GEORGE WIMPEY & CO. LTD., have established the principles upon which a joint contract is to be drawn up for the construction and equipment of a hydro-electric power project at Hirfanli, on the River Kizilirmak, about 65 miles from Ankara. At Hirfanli, a rock-filled dam, 280 ft. high will be built, and a 100,000-kW hydro-electric power station constructed. The whole of the civil works and construction will be undertaken by George Wimpey & Co. and all the permanent generating plant, transformers and switchgear supplied and installed by the English Electric Co. The electrical equipment consists of four vertical Francis-type water turbines and valves, four alternators, four transformers, six outdoor circuit-breakers, isolators, control equipment and power-station auxiliaries. Each turbine is rated at 35,000 maximum h.p., rotating at 250 r.p.m. The alternators are 31,250 kVA, 0·8-p.f. 11,000-volt three-phase 50-cycle machines and the transformers, three-phase units with on-load taps and forced-air cooling.

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LAUNCHES AND TRIAL TRIPS

M.S. "HAZELMOOR."—Single-screw cargo vessel, built and engined by R. and W. Hawthorn, Leslie & Co., Ltd., Hebburn-on-Tyne, County Durham, for the Moor Line, Ltd. (Managers: Walter Runciman & Co., Ltd.), Newcastle-upon-Tyne. Main dimensions: 423 ft. between perpendiculars by 58 ft. by 29 ft. to upper deck; deadweight capacity, about 9,540 tons on a draught of 25 ft. 8¾ in.; gross tonnage, 5,580. Hawthorn-Doxford four-cylinder opposed-piston combined-stroke oil engine, developing 3,300 b.h.p. at 108 r.p.m. and a service speed of about 13 knots. Trial trip, March 23.

M.S. "BERGEBOSS."—Twin-screw oil tanker, built and engined by Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for Skibsaktieselskabet Snefonn (Managers: Sig. Bergesen d.y. & Co.), Stavanger, Norway. Fourth tanker built for these owners. Main dimensions: 625 ft. between perpendiculars by 86 ft. by 45 ft. 9 in.; deadweight capacity, 32,250 tons on a draught of about 34 ft. 3 in.; oil-cargo capacity, 1,540,000 cub. ft. Two B. and W. six-cylinder single-acting two-stroke Diesel engines, each developing 6,900 i.h.p. Speed, 15½ knots, fully loaded. Launch, March 25.

M.S. "NORFOLD."—Single-screw oil tanker, built and engined by the Götaverken Shipyard, Gothenburg, Sweden, for Hvalfanger A/S Vestfold (Managers: Johan Rasmussen & Co.), Sandefjord, Norway. Main dimensions: 550 ft. overall by 66 ft. by 39 ft. 3 in; deadweight capacity, about 17,400 tons on a draught of 30 ft. 2½ in. Götaverken nine-cylinder two-stroke single-acting Diesel engine developing 6,750 b.h.p. at 112 r.p.m. Loaded speed, about 15 knots. Launch, April 1.

M.S. "WROXHAM QUEEN."—Single-screw trawler, built by Cochrane and Sons, Ltd., Selby, Yorkshire, for Talisman Trawlers, Ltd., West Hartlepool. Main dimensions: 100 ft. between perpendiculars by 22 ft. by 10 ft. 9 in.; gross tonnage 200. Six-cylinder direct-reversing Diesel engine, developing 350 b.h.p. at 250 r.p.m., constructed by the Crossley Brothers, Ltd., Openshaw, Manchester, 11, and installed by the Drypool Engineering and Dry Dock Co., Ltd., Hull. Launch, April 5.

M.S. "MINKARA."—Single-screw cargo vessel, built by the Grangemouth Dockyard Co., Ltd., Grangemouth, for the Adelaide Steamship Co., Ltd., London, E.C.3. Main dimensions: 290 ft. by 44 ft. 6 in. by 22 ft. 3 in; deadweight capacity, about 3,450 tons on a mean draught of 19 ft. Burmeister and Wain five-cylinder Diesel engine, developing 2,100 b.h.p. at 170 r.p.m. Loaded speed, about 12 knots. Launch, April 5.

S.S. "BALLARAT."—Single-screw cargo vessel, built and engined by Alexander Stephen and Sons, Ltd., Glasgow, for the Peninsular and Oriental Steam Navigation Co., London. Designed for the company's Australian wool trade. Main dimensions: 490 ft. between perpendiculars by 69 ft. by 43 ft. to shelter deck; deadweight capacity, 12,790 tons on a draught of about 29 ft. 9 in.; gross tonnage, 9,300. Triple-expansion geared steam turbines developing 11,000 s.h.p. on service. Steam supplied by two Foster Wheeler boilers. Service speed, 18 knots. Launch, April 6.

M.S. "BORDER LASS."—Single-screw oil tanker, built and engined by William Doxford & Sons, Ltd., Sunderland, for the Lowland Tanker Co., Ltd., Newcastle-upon-Tyne. Main dimensions: 515 ft. by 69 ft. 6 in. by 37 ft. 6 in.; deadweight capacity, 16,030 tons on a draught of 30 ft. 0½ in. Doxford six-cylinder opposed-piston oil engine. Trial trip, April 6.

NOTICES OF MEETINGS

Chemical Society

LONDON
"The Story of the *iso*Quinoline Alkaloids," by Dr. R. H. Manske. Centenary Lecture. Thurs., May 6, 7.30 p.m. Reception and Conversazione. Senate House, University of London, Russell-square, W.C.1. Fri., May 7, 6.30 p.m.

BANGOR
"Atoms and Molecules in Cages," by H. M. Powell. North Wales Branch. Department of Chemistry, University College of North Wales, Bangor. Thurs., May 6, 5.45 p.m.

DUNDEE
"The Relation Between Theory and Experiment in Physical Chemistry," by Professor E. A. Guggenheim. Chemistry Department, University College, Dundee. Thurs., May 6, 5.15 p.m.

SOUTHAMPTON
"The Stereochemistry of *cyclo*Hexane Derivatives," by Professor D. H. R. Barton. Chemistry Department, The University, Southampton. Fri., May 7, 5 p.m.

Institute of Marine Engineers

LONDON
"Marine Diesel Engines: Harland and Wolff Types," by C. C. Pounder. Junior Lecture. Mon., May 3, 6.30 p.m.

Institute of Metals

BIRMINGHAM
Annual General Meeting and Chairman's Address. Birmingham Local Section. James Watt Memorial Institute, Birmingham. Tues., May 4, 6.30 p.m.

Institution of Civil Engineers

LONDON
"River Severn Scheme for the Water Supply of Coventry," by R. le G. Hetherington and J. C. A. Roseveare, Jun. Public Health Engineering Division. Tues., May 4, 5.30 p.m.

BIRMINGHAM
Annual General Meeting. Midlands Association. James Watt Memorial Institute, Birmingham. Thurs., May 13, 6 p.m.

Institution of Electrical Engineers

LONDON
"The Reflection and Absorption of Radio Waves in the Ionosphere," by W. R. Piggott; and "Some Notes on the Absorption of Radio Waves Reflected from the Ionosphere at Oblique Incidence," by Dr. W. J. G. Beynon. Radio Section. Wed., May 5, 5.30 p.m.
"Electric Traction Using Single-Phase 50-c/s Current," by M. Garreau; and "Electric Locomotives on the Valenciennes-Thionville Line," by F. Nouvion. Ordinary Meeting. Thurs., May 6, 5.30 p.m.
"Measurement as a Factor in Understanding," by Dr. K. J. R. Wilkinson. Measurements Section. Tues., May 11, 5.30 p.m.

BIRMINGHAM
"Safety in the Use of Portable and Transportable Electrical Equipment in Industry," by J. W. Bunting. South Midland Centre. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., May 3, 6 p.m.

LEEDS
Annual General Meeting. North Midland Centre. Offices of the Yorkshire Division, British Electricity Authority, 1 Whitehall-road, Leeds. Tues., May 4, 6.30 p.m.

MANCHESTER
"Some Applications of the Electrolytic Tank to Engineering Design Problems," by H. Diggle and E. R. Hartill. North-Western Centre. Engineers' Club, Albert-square, Manchester. Tues., May 4, 6.15 p.m.

NEWCASTLE-UPON-TYNE
Faraday Lecture on "Electro-Heat and Prosperity," by O. W. Humphreys. North-Eastern Centre. City Hall, Newcastle-upon-Tyne. Tues., May 4, 7 p.m.

Institution of Mechanical Engineers

LONDON
"The Development and Scope of Work Study," by R. M. Currie. Industrial Administration and Engineering Production Group. Tues., May 4, 5.30 p.m.
"The Accountancy Service to Works Management," by C. E. Power. Industrial Administration and Engineering Production Group. Fri., May 7, 5.30 p.m.
"Rapid Starting Technique: Some Significant Tests at Poole Power Station," by J. S. Hall and A. F. Britton. Steam Group. Fri., May 14, 5.30 p.m.
"Standardisation," by R. F. Holmes. Annual General Meeting. London Graduates' Section. Tues., May 4, 6.30 p.m.

SWANSEA
"Combustion in Compression-Ignition Oil Engines," by Professor S. J. Davies. Repetition of the address by the chairman of the Automobile Division. South Wales Branch. Mackworth Hotel, Swansea. Fri., May 7, 6 p.m.

Institution of Production Engineers

BIRMINGHAM
"Work Study and the Production Engineer," by R. Guthrie. Birmingham Graduate Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Tues., May 11, 7 p.m.

LEEDS
Annual General Meeting and Film Evening. Yorkshire Graduate Section. Great Northern Hotel, Leeds. Sat., May 1, 2.30 p.m.

Institution of Structural Engineers

CARDIFF
Annual General Meeting. Wales and Monmouthshire Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., May 11, 6.30 p.m.

Leeds Metallurgical Society

LEEDS
Annual General Meeting and Film Evening. Chemistry Department, The University, Leeds 2. Thurs., May 6, 7.15 p.m.

Modular Society

LONDON
"Towards New Building," by J. H. Forshaw. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Wed., May 5, 7.30 p.m.

Royal Aeronautical Society

LONDON
"Propellers for High-Speed Aircraft," by G. C. I. Gardiner. Section Lecture. Tues., May 4, 7 p.m.

The Royal Society

LONDON
"Soil Metabolism," by J. H. Quastel. Leeuwenhoek Lecture. Thurs., May 6, 4.30 p.m.

Royal Society of Arts

LONDON
"The Society's House and Earlier Homes," by John N. Summerson. Peter Le Neve Foster Lecture. Wed., May 12, 2.30 p.m.

Society of Engineers

LONDON
Conversazione. Science Museum, Cromwell-road, South Kensington, S.W.7. Tues., May 4, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 36 Portman-square, London, W.1. (WEI beck 6813.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Leeds Metallurgical Society, Department of Metallurgy, The University, Leeds, 2.
Modular Society, 22 Buckingham-street, London, W.C.2. TRAfalgar 4567.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Society of Engineers, 17 Victoria-street, London, S.W.1. (ABBey 7244.)